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# EXPERIMENTS WITH HOT-WATER TREATMENT OF DAFFODILS IN RELATION TO FORCING AND FIELD CULTURE

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## INTRODUCTION

The work recorded in this circular continued from July, 1926, to the spring of 1929 and was undertaken for the purpose of improving the health and vigor of the daffodil stocks which have been grown at the United States Bellingham Bulb Station, Bellingham, Wash., in some cases for a score of years. (Fig. 1.) The treatments employed have to do solely with these experimental stocks in an investigational way and bear no relation to the Federal plant-quarantine regulations, which are prepared, promulgated, and administered for an entirely different purpose.

The exigencies of the situation, the demands upon the writer's time, and the general labor conditions required certain modifications of prescribed methods in order to accomplish the task of getting the stocks processed. It was necessary that the stocks dug late in June and early in July be treated and put back in the ground by September 1, a necessity that may also confront the practical grower.

It was necessary that the bulbs be treated three or four weeks earlier than is commonly advised and that the treating be done at the Bellingham Bulb Station and the forcing in Virginia. It was also necessary that one bulk shipment be made from Bellingham to North Carolina after such comparatively early treatment.

Were one planning experiments with nothing else in view, some of these factors would most likely be modified. The methods fol-

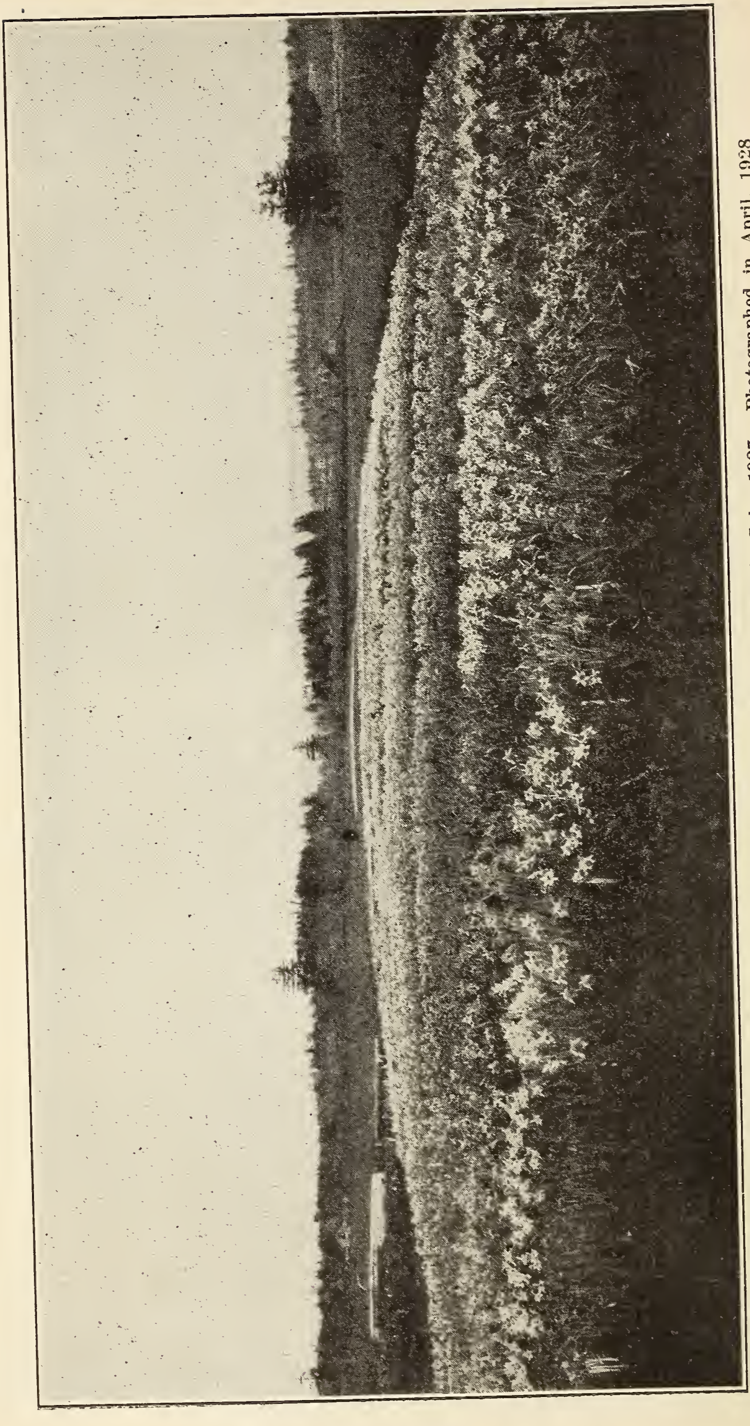


FIGURE 1.—A half acre of more than 100 small lots of daffodils treated in July, 1927. Photographed in April, 1928

lowed, however, have not been without advantage, for they have shown that the hot-water treatment admits of greater flexibility than is commonly supposed, as to the date of processing, the degree of heat, and the duration of the period of application when planting stock only is considered. It is hoped that the data are presented with sufficient clarity for the reader to form his own conclusions regarding reactions by referring to the batch number to see exactly the treatment used.

## THE CLIMATIC FACTOR

The climate of the Puget Sound region is particularly favorable to the culture and handling of daffodils. There is a decided advantage in low temperatures, not only for the best development of inflorescence and bulbs but also for the most advantageous handling during the season the bulbs are out of the ground. This is particularly applicable in case the hot-water treatment is given, for the bulbs can be brought back promptly to a temperature of 70° F. or lower without resort to artificial cooling.

The season of 1927 was unusually warm for the Bellingham region, but notwithstanding this the temperatures in the basement of the bulb house, where most of the bulbs were handled, seldom rose above 70° F. during the hottest part of the day.

Attention is also directed to the fact that but slight injury resulted to the stocks exposed to the sun for a time after treatment. This needs elucidation. Such practice could not be defended in many situations, but on Puget Sound in late July and August the effect of the sun's rays is very much mitigated by the prevailing haze and smoke, rendering the sunning of the stocks much less injurious.

A low, equable temperature always prevails, and there is an abundant supply of moisture during the growing season. Normally the rainfall ceases the last half of June. The bulbs are ready to be dug early in July; consequently maturity and drying off coincide. These conditions are admirable for the production of clean, hard bulbs, well matured. It does not follow, however, that the stocks are dry when dug. It simply means that they are drying. The ground may not become dry before sometime in August.

## HISTORY AND CONDITION OF THE BELLINGHAM STOCKS

Since the work has been based largely on the stocks grown for a period of years at Bellingham, Wash., it will be interesting and significant to know the origin, history, and previous condition of the materials which were treated. This collection probably furnishes the most reliable information on the character and behavior of imported stocks that it is possible to get in this country.

Many of the varieties have been grown in greater or less numbers since the bulb work was begun 20 or more years ago, with additions coming in irregularly from year to year ever since. Some of the lots have been kept intact from the date of importation, while others have been combined with later accessions of the same variety. The older Barrii and Incomparabilis forms are the ones likely to be the same as imported, while the modern commercial trumpets are more likely to have received admixtures of other importations, although some of them are pure descendants of the original accessions of 15 to 20 years ago. One stock of King Alfred has been kept distinct since 1912. Empress, Horsfieldii, Madame Plemp, Princeps, Ard Righ, Obvallaris, Sir Watkin, and one stock of Victoria were among the earliest importations.

There was no regularity in adding to the collection, but importations were emphasized in certain years. In 1917 there were added Van Waveren's Giant, Glory of Noordwijk, Weardale Perfection, one stock of King Alfred, and a number of others, in quantities of 100 to 1,000 mature bulbs. The year 1923 witnessed the accession of a large number of newer varieties. These were mostly small quantities of surplus small bulbs from the writer's private collection grown in the District of Columbia for four or five years previous.

The quality of the stock has varied greatly from year to year. As it is viewed in retrospect, the conditions are usually accounted for. For the first 10 years the culture was on a 6 to 7 acre tract where it was possible to shift occasionally from a sandy loam to a silt loam soil; but crowded conditions of culture, making it difficult to maintain sanitation and fertility, reacted rather badly on quality.

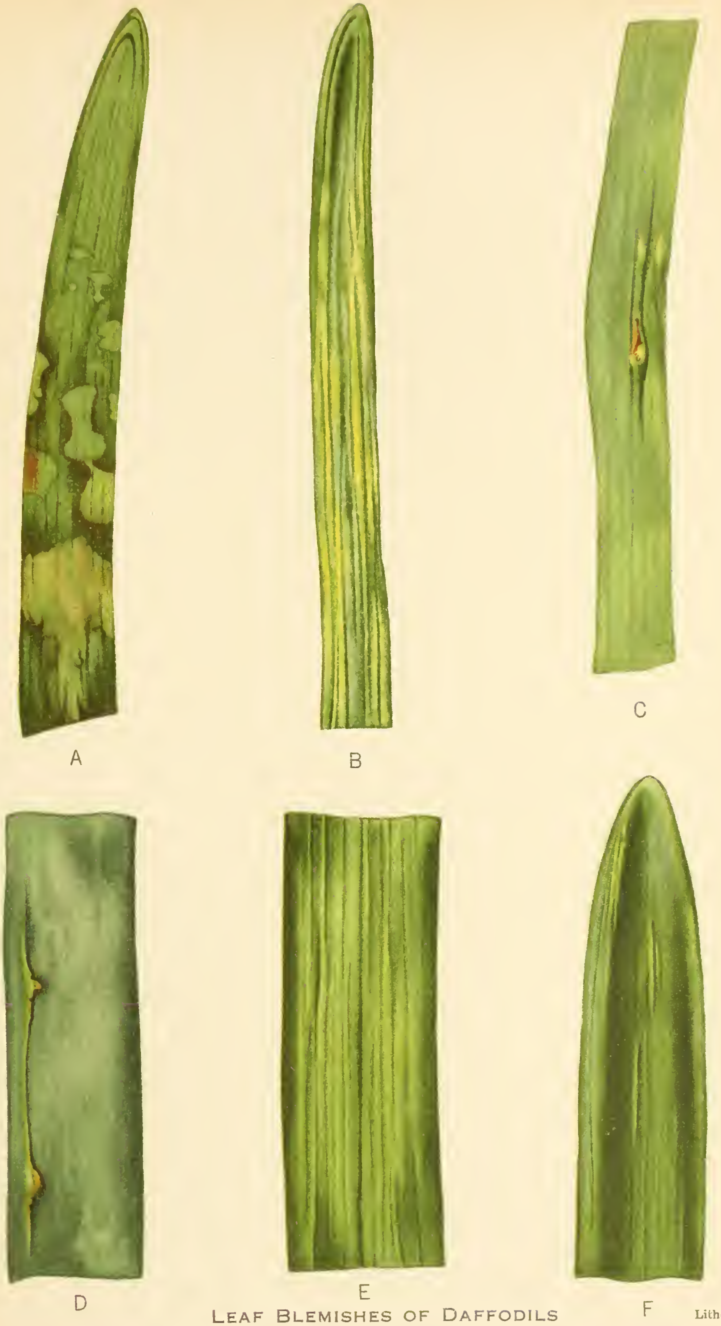
In 1917 all the stocks were moved to a tract of black sandy loam of good fertility. The effect on the quality of the stock was phenomenal. The quality held good for two or three years after the removal to Whatcom silt loam freshly removed from the forest, but sagged again when, after two or three years of culture, the forest débris of the soil became depleted.

Since 1925 the condition of the stocks has advanced decidedly, owing to several factors. Among these are tile drainage of the soil, deeper tillage, culture on freshly rotted sod, and more liberal use of artificial fertilizers. Up to 1924 dependence was placed mainly on small quantities of animal manures and cover crops for fertility, but since that time much larger cover crops have been supplemented with artificial fertilizers, with emphasis on the phosphate and potash elements.

The plantation has always been infested with narcissus fly (*Mérodon equestris*). The method of control up to 1926 consisted in culling out the infested bulbs at each digging and gouging them out in the spring as the plants came up. These methods proved to be palliative, as would be expected. They kept the fly in check and the losses moderate.

In the summer of 1926 for the first time the hot-water treatment was applied to less than half of the stocks, all the bulbs that were dug that year. This treatment was extremely effective, there being a very remarkable decrease of infestation as well as a very noticeable diminution of the flies on the wing the next year.

It was not difficult, however, to account for such a clean-up. It was noted during the harvesting of 1926 that the general stocks were clean to only slightly infested with the fly, but four beds of 4-year-old seedlings which had been undug for two years were in a badly infested condition. Portions of rows had disappeared, and nothing was left but the outer coats of the bulbs. The larvæ of the fly were very numerous in these small bulbs, which, of course, were planted



LEAF BLEMISHES OF DAFFODILS

Litho. A. Hoen & Co., Inc.

A.—Effect of late hot-water treatment on leaves of King Alfred.
B.—Yellow stripe in Golden Spur.
C.—Lesions of nema infestation (*Tylenchus dipsaci*).
D.—Effect of hot-water treatment on leaves of Great Warley (batch 7).
E.—Mottling in leaves of White Queen.
F.—Effect of hot-water treatment on leaves of Van Waveren's Giant (batch 1).

shallow, and a large percentage of them was completely ruined. Another factor contributing to the remarkable clean-up of 1926, when less than one-half of the bulbs were treated, is considered to be the decision in 1925 that deeper planting was necessary. The plantings of 1925, which were the ones undug in 1926, were therefore put down an inch or more deeper than usual. If this deep planting contributed, as the writer believes it did, to the clean-up of the stock, it indicates that shallow trap plantings scattered through the field might prove to be an aid in reducing fly infestation. The condition of the seedlings mentioned above is proof of this.

The most remarkable fact in connection with the plantings has been the paucity of eelworm infestation. (Pl. 1, C.) Constant watchfulness has been exercised for evidence of this parasite, and the stocks were gone over by no less than three professional nematologists on four occasions in the last 12 years.

The only infestation of nemas recognized in the stocks by anybody was received through one Netherlands firm in 1917. This was evident the first year in three varieties. In 1927 a very slight infestation was found by Gerald Thorne in the progeny of another lot received from this firm at the same time. It is rather remarkable that with the reported wide prevalence of *Tylenchus dipsaci* it should not have been more abundant in these stocks, gathered together as they have been from various sources, but most of them from the Netherlands.

The writer has long been convinced that the prevalence of the eelworm disease in modern daffodil stocks has been very much overstated. It was supposed at one time that the hyacinth stocks at the Bellingham Bulb Station were also badly infested, but a careful examination one season by L. P. Byars, assisted by the writer, revealed the astounding fact that the phenomena observed were caused by improper handling of the stocks.

Since 1916 no nema infestation has been detected in the hyacinths, and careful search of 200 or more lots of daffodils has revealed only 4 harboring this organism, and all of these were received the same season from one Netherland firm.

The groups of daffodil ills variously referred to as mosaic, gray disease, virus disease, yellow stripe, etc., have been present in various proportions and in various forms. (Pl. 1, B and E.) Many stocks are quite free, while others are all " gray." Sir Watkin has usually been in good condition, but during three years, when the demand on the station for stocks was heavy and the turn-off consequently close, the remaining bulbs were badly striped. The same was true of Golden Spur stocks (pl. 1, B) under like circumstances. The stocks of M. J. Berkeley have all been gray since the beginning. Ariadne and White Queen (pl. 1, E) have a mottled condition of the foliage, but it is a very different phenomenon from that described in connection with the previously named varieties, and the plants do not appear to be reduced in vigor.

The hot-water treatment so far as known has no effect on this group of imperfections. As with similar maladies in many other groups of plants, the only remedy is the elimination of the affected individuals. They should be gouged out and destroyed. A faithful effort for two years has improved a badly affected stock of Sir Watkin so that it is in good condition. But with this variety as well as some others, particularly Conspicuus and Princeps, annual inspection and roguing should be practiced to maintain purity of stock, because a few affected plants appear from year to year, but the trouble does not seem to spread to contiguous stocks of other varieties.

The treatments given in 1926, while intended to be run up to the limit of endurance of the stocks, were largely in the nature of experiments conducted for the purpose of gaining experience with the hot-water process and learning the handling of a machine which was not only untried but constructed on an untried principle. It was intended that the main treating should be done in 1927.

The operations of the season of 1926 (which were reported in a floral journal [1]) did not differ essentially from those of 1927, except that in the course of the year's experience the operations were refined a little and that in 1927 temperatures were controlled with a more closely graduated thermometer.

In 1926 the temperature was read by means of an ordinary dairy thermometer with but one graduation for 2 degrees. The instrument used in 1927 had one graduation to each fifth of a degree and was accurate to within one-tenth of 1 degree at the critical temperature of 110° F. The dairy instrument used in 1926, however, was accurate when compared with a Weather Bureau standard set, as far as an ordinary visual test revealed.

When the treatments were begun in 1926 it was fully realized that the stocks of many varieties were by no means perfect and that such imperfections were not due to infestations of nema or fly. In many cases the bases were eroded, thin, and large, and bore an imperfect circle of roots. The natural glaucous color of most daffodil leaves was a glossy green in places, and the foliage and portions of the stems bore light, rusty brown areas and lines which more or less deformed them.

Early European experiences indicate a benefit to the stocks from the hot-water treatment beyond the simple killing of the nema and the fly. The inference has been that there is a physiological effect from the treatment which increases the vigor of the stocks.

It was not until toward the end of the forcing tests of 1927 that it was definitely demonstrated that the stocks were injured by another organism which has hitherto not been reported upon as a pest of the daffodil. This is a mite [2] which inhabits the interior of the bulb. This same mite was discovered in 1925 in Pennsylvania by C. F. Doucette, of the Bureau of Entomology, and has since been found by him in various localities on the Pacific coast. Its presence in these stocks was demonstrated two years before, but its importance was not clearly recognized at that time. It is considered now that the largest measure of beneficial influence of the hot-water treatment on the vegetative vigor of the Bellingham stocks is due to the elimination of this organism. It may well be that this does not cover it all, but it seems certain that it does cover a large part of that residual beneficial effect which has been called "pepping up" of the stock. Of course, it is well recognized that the ordinary "bulb mites"

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[1] GRIFFITHS, D. HOT-WATER TREATMENT OF DAFFODILS IN 1926. Amer. Florist 68 (2039): 2, 8, illus.

[2] *Tarsonemus approximatus* Banks (new variety). Determined by H. E. Ewing, Bureau of Entomology, U. S. Department of Agriculture.

(*Rhizoglyphus* spp.) are also killed by the treatment. The destruction of this organism doubtless improves the vigor of the bulbs also, but Tarsonemus apparently has been the injurious organism. This view is strengthened by the observation that treating recently treated bulbs does not produce such an invigoration.

## RELATION OF TREATMENT TO DIGGING

The first three treatments in 1927 followed immediately upon the digging of the respective lots of bulbs. The other and more general work of treating varied to such an extent that it is not possible to specify the intervening period, usually referred to as "curing," except in a general way. The time of the beginning of the treatments and the finishing of digging does not indicate the actual conditions, for digging continued over a period of a little more than four weeks and was by no means continuous or in rotation. It is important to bear this in mind, because experiments in establishing the hot-water treatment required by quarantine regulations have shown that flower injuries are largely dependent on the time elapsing between digging and treatment.

In spite of the above, it is possible to segregate the stocks into groups, thus narrowing the recognizable space between digging and the treatment. About one-sixth of an acre was dug June 16, 1927, before the bulbs were mature, for reasons that do not pertain to the subject at hand. The tops, all perfectly green and functioning, were hoed off, and the bulbs dug and spread thinly on shelves under thorough aeration until treated, July 22 to July 25. The plantings of 1925 were all dug by July 9, but it took until the 14th to dig the last of the 1926 plantings, all of the latter also being treated in 1926. As will be seen from Table 1, the treatment, except that of the first three batches, began July 19, five days after all digging was completed; but the first treatments were of the earlier of the normally dug bulbs, so that in general it can be said that about two weeks intervened between the digging of any of the varieties and their treatment.

Of the general treatment, some of the small lots handled in batch 14 on July 25 were the last to be dug. Their period of drying was therefore shorter than any except that of the varieties in batches 1 to 3 treated immediately upon digging.

## THE MACHINE

The machine used in the processing is usually referred to as the Bellingham "bulb cooker." It was described in two publications[3] in 1926. It holds its temperature like a thermos bottle.

The apparatus consists essentially of a steam boiler for heating; a wooden tank constructed of 2½-inch fir lumber 30 inches wide, 42 inches high, and 7 feet long, inside measurements; an agitator with 8-inch blades operated by an electric motor; and a ½-inch steam muffler or noiseless water heater for admission of the steam into the water. (Fig. 2.) The agitator operates below a slatted false bottom

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[3] GRIFFITHS, D. BELLINGHAM BULB "COOKER." Florists' Rev. 58 (1506): 37–38, illus. (Also published as The bulb "cooker." Amer. Soc. Hort. Sci. Proc. (1926) 23: 171–173, illus. [1927.])

11 inches above the floor of the tank. Steam is admitted into the tank through a ½-inch pipe on a level with the propeller shaft and is discharged through the injector in front of and on a level with or slightly below the axis of the propeller. (Fig. 3.)

The tank is fitted with a cover of uniform construction, made reversible to compensate for the inevitable warping to which it is subjected. The articulation of the cover with the tank is made tight by a ⅜-inch felt gasket tacked to the edge of the tank except on the front side, where it is removable to facilitate loading and unloading. The cover is held in place and the articulation with the tank tightened by two levers whose fulcrums are the joists of the ceiling. The heavy cover is raised and lowered by a tackle.

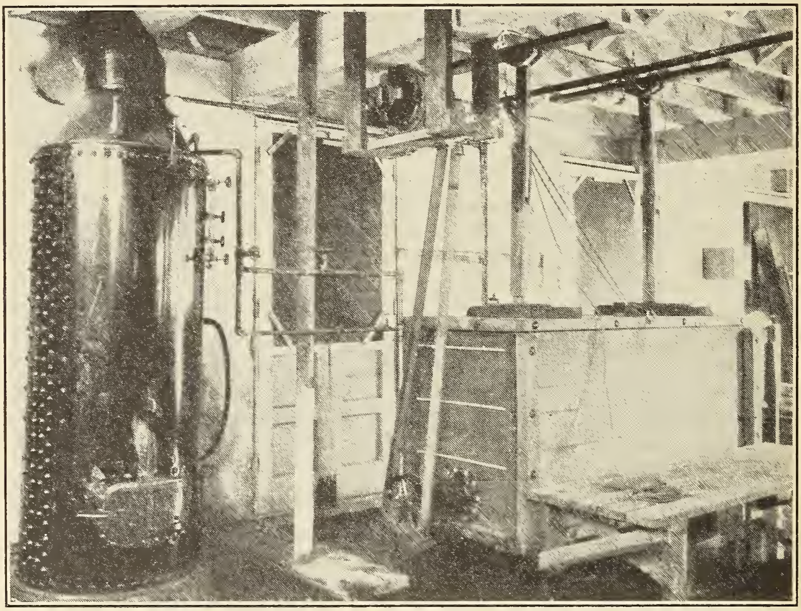

FIGURE 2.—The Bellingham "bulb cooker" as operated in 1927

For safety, three valves, two globe and one needle, are employed. The globe valves are on the main ¾-inch line admitting steam into the tank. The needle is on a ½-inch by-pass for finer adjustment.

The control is by means of the hand valves only, and a check on the temperature is kept by a thermometer inserted through the cover near its center.

The thermometer is specially constructed. It is a cylindrical bulb, mercury-filled instrument 15 inches long, graduated to one-fifth of a degree, and has a scale of 60° to 120° F. Its calibration shows it to be one-tenth of a degree low at a temperature of 110°. This error has been disregarded in all the readings.

## THE TREATMENTS

The operation of this treating machine is simple. Its main advantages are its slow change of temperature due to the well-insulated tank, its delicate response to heat due to the admission of steam directly into the water through a steam muffler, and its simple but very efficient control through the use of a single needle hand valve during the most critical period, requiring little or no attention during five-sixths of the processing period.[4]

The "noiseless water heater or steam muffler" creates perfect circulation in the tank without the use of the agitator when the water is being heated preparatory to putting in the bulbs. When the vat is charged, more thorough mixing is obtained by the use of the propeller.

The bulbs are placed in burlap sacks, filled preferably not too full. Each package is marked with a wired tree label which can be used several times if care is taken to abbreviate and condense the inscription.

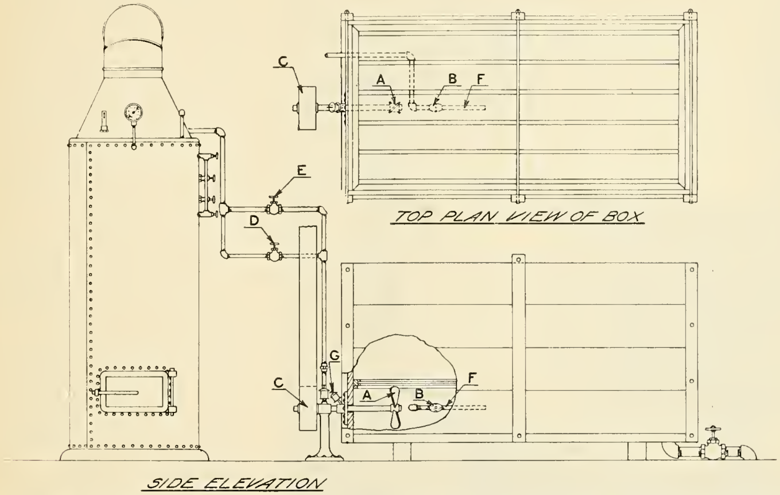

FIGURE 3.—Plan of the Bellingham "bulb cooker": A, Propeller; B, steam muffler; C, propeller pulley; D, needle valve; E globe valve; F, 10-inch piece of 1-inch pipe; G, grease cup

It has been the practice to heat the water a few degrees above the maximum for processing preparatory to loading the vat. Commonly a temperature of 115° or 116° F. has been used initially. It takes 3 to 5 minutes to put the bulbs in, when the temperature may drop to 100° to 105°. The loading of the bulbs always leaves the tank level full of water. The heavy lid is then lowered into place by tackle and clamped down by the levers which function against the joists of the ceiling. The whole operation of loading and fastening on the cover does not usually occupy more than 5 minutes. The advisability of raising the temperature of the water to 115° or 116° has been questioned. If planting stock alone is under consideration the matter is unimportant. With forcing stock every possible precaution is advisable, but the writer does not consider that there is any injury from this source.

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[4] The machine has now been thoroughly tested by at least four growers in the Pacific Northwest and one each in Virginia, Maryland, and Michigan. Three of the machines in the Northwest are operated in the open.

The water is now thoroughly agitated by turning on the motor which operates the propeller. The steam is then turned on cautiously by way of the needle valve. It has been shown that even the needle valve may be dispensed with, the amount of steam being controlled entirely by the less delicate globe valve. In this machine, with very violent agitation through the propeller and a very efficient mix by the injector, there is no danger of injury through unequal distribution of heat. When the thermometer, which projects 6 to 8 inches into the water through an auger hole in the center of the cover, registers the maximum intended for the treatment, the valve is closed until the cold bulbs have been heated through, thus lowering the temperature of the water. It takes 20 to 30 minutes for the heat to penetrate large bulbs; consequently during this time attention must be given to the thermometer and to the steam valve controlling the steam being admitted to the tank, in order to maintain the temperature at or near the maximum. When this initial period of attention has passed the steam is permanently cut off, the propeller run for a few minutes longer, and then stopped. During the remainder of the 3-hour period (about two and one-half hours) no attention to the tank is necessary, since it will stand normally that long without a drop of more than 1°. It has been the practice to operate the propeller for a few minutes about the middle of the period to prevent any possibility of stratification in the tank. With a poorer insulation more rapid cooling would take place, necessitating an admission of steam as the thermometer indicated. This, however, has not been found necessary with the present installation in any full 3-hour period of treatment, but has been necessary in a 4-hour period.

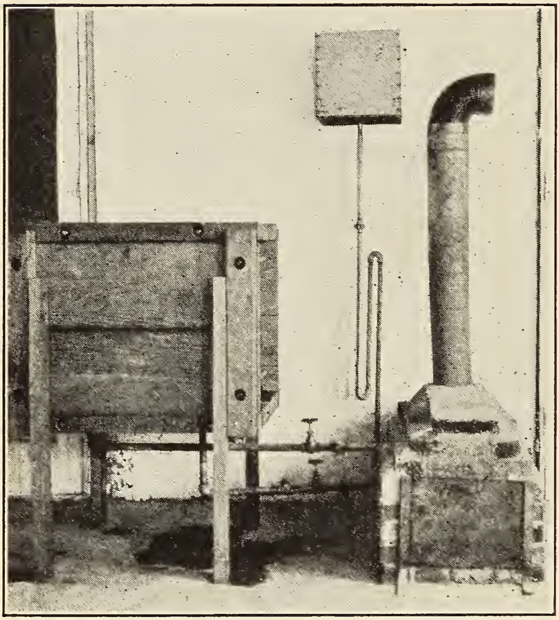

FIGURE 4.—The small treating unit operated with a hot-water heating system

The unloading of the bulbs at the close of the period occupies but a few minutes. The sacks are removed from the tank and piled on a platform or truck. This allows them to drain sufficiently in the time that it takes to unload. They are then ready to be emptied on the shelves as soon as the last bag has been unloaded, or as soon as the next batch has been loaded if the treating is continuous, as is usually the case.

In Table 1 an endeavor has been made to give as accurate a picture as possible of just what was done in connection with each batch treated. The first three batches were treated in the small machine (fig. 4), which, on account of its small size and radiating heating surface in the tank, is neither as sensitive nor as stable as the larger machine; but while not so desirable for experimental work, it is considered a very satisfactory machine for the small grower who needs to treat but a few bulbs and can not afford a commercial treating plant.

The table records the time and the temperature of the water when loading began. Under "Loading" is recorded the time and the temperature immediately after the bulbs were in place in the vat. Under "Initial period" is recorded the time at which it was estimated the bulbs were heated through and the temperature at the close of that period. This represents the time when the steam was turned off in the large machine. The propeller was usually run a few minutes beyond this. The columns headed "Extra heat" are designed to show the point to which the heat had been depressed at the time more steam was admitted and the degree to which the mass was raised at this time. Under "Finish" is recorded the time of unloading and the temperature at the moment unloading began.

TABLE 1.—*Tabulation of hot-water treatments of daffodil bulbs*

| Batch No. | Date | Start | | Loading | | Initial period | | Extra heat | | Finish | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | July 7 | Time | Temperature | Time | Temperature | Time | Temperature | Time | Temperature | Time | Temperature |
| | | | °*F.* | | °*F.* | | °*F.* | | °*F.* | | °*F.* |
| 1 | July 7 | 12.25 | 114.8 | 12.27 | 114 | 12.50 | 112.4 | 2.30 | 110.4–112.2 | 3.30 | 111.4 |
| 2 | July 8 | 11.15 | 114 | 11.20 | 109.4 | 11.40 | 112.6 | 1.30 | 110.8–112.4 | 2.45 | 111 |
| 3 | July 12 | 8.25 | 113 | 8.29 | 111.8 | 8.40 | 112.2 | 10.05 | 110.6–112.4 | 12.30 | 110.2 |
| 4 | July 19 | 8.00 | 115.6 | 8.10 | 106 | 8.35 | 111.8 | | | 11.15 | 111 |
| 5 | do | 11.25 | | 11.30 | 98 | 11.55 | 111.8 | | | 2.30 | 110.8 |
| 6 | July 20 | 7.55 | 114.4 | 8.00 | 107.8 | 8.25 | 111.4 | | | 11.00 | 110.4 |
| 7 | do | 11.05 | 108 | 11.10 | 94 | 11.45 | 111.6 | | | 2.15 | 110.4 |
| 8 | July 21 | 8.15 | 115.4 | 8.20 | 104 | 8.45 | 113.4 | | | 11.15 | 112.6 |
| 9 | do | (1) | | 11.25 | 103 | 11.45 | 111 | | | 2.20 | 109.8 |
| 10 | July 22 | 8.15 | 113 | 8.25 | 96 | 9.00 | 111.4 | | | 11.15 | 110.6 |
| 11 | do | (1) | | 11.50 | 106.4 | 12.15 | 111.6 | 2.30 | 110.4–111.2 | 3.50 | 110.8 |
| 12 | July 23 | 8.05 | 115.2 | 8.15 | 110 | 8.45 | 111.4 | | | 11.15 | 110.4 |
| 13 | July 25 | 9.30 | 114 | 9.35 | 104 | 10.00 | 113.4 | | | 12.30 | 112.4 |
| 14 | do | 12.50 | (1) | 12.55 | 107 | 1.15 | 110.8 | 2.30 | 110.0–111.0 | 3.45 | 110.4 |
| 15 | July 26 | 8.20 | 114 | 8.25 | 106 | 8.45 | 111 | | | 10.00 | 110.1 |
| 16 | do | 10.10 | (1) | 10.20 | 104 | 10.50 | 112.8 | | | 11.45 | 112 |
| 17 | do | 1.25 | 113 | 1.30 | 104 | 1.55 | 111.2 | | | 3.00 | 110.6 |
| 18 | July 27 | 8.45 | 112.4 | 8.55 | 106 | 9.15 | 111.4 | | | 10.25 | 111 |
| 19 | do | 10.40 | | 10.50 | 108 | 11.05 | 111.4 | | | 12.30 | 110.8 |

[1] These treatments followed immediately upon the unloading of the previous batches.

In the case of only two batches was it necessary to admit more heat to the big tank after the preliminary period of about 30 minutes. This was in batches 11 and 14. In batch 11 the period of treatment was extended to 4 hours. This was done because a nematologist after making a careful examination of the stocks in the spring found one infested bulb, and on this account it was decided to take extra precautions. This means that while this machine will maintain its temperature satisfactorily without the admission of extra heat for two and one-half hours, it will not hold within the prescribed limit for three and one-half hours without the admission of more steam.

In batch 14 there were treated a large number of small lots, many of which were choice varieties. The temperature at the close of the initial period (the highest used in all cases after the loading) was only 110.8° F. The machine would not hold within four-fifths of a degree for two and one-half hours. At 2.30 p. m. the temperature had dropped to 110°, so steam was admitted to raise it to 111°.

There was a variation of a fraction of a degree in the maintenance of temperature in the tank in different batches. Several factors may enter into this variation. Atmospheric temperature, wind, the degree to which windows and doors were kept closed in the treating room, and the setting of the loose portion of the gasket on the edge of the tank upon which the cover impinged may all have contributed to the result.

## AFTERTREATMENT AND TRANSPORTATION OF THE BULBS

Practically all the material treated in these experiments was grown at the Bellingham Bulb Station, and the forcing tests were conducted at the Arlington Experiment Farm, Rosslyn, Va. The method of handling the stocks after treatment and before "flatting up" is therefore of importance.

It has been stated that the bags of bulbs from the treating vats were emptied promptly in thin layers on shelves in the bulb house. About one-third of the wall space of the building is occupied by paneled French doors extending from near the ceiling to the floor. These were kept constantly open, thus assuring the freest circulation of air. Even in such a favored situation it is considered necessary to exercise watchfulness for several days until the bulbs are dry. The heaviest layers were disturbed occasionally by running a hand under them to bring the poorly aerated bulbs and portions of bulbs to the surface.

In order to accommodate the stocks in thin layers, some shelves were built on the north side of a building where all of batches 4, 5, and a part of 6 were dried. The others were dried in the bulb house. Only those on the upper shelf outside were subjected to actual sunning, the rest being in the shade but well aerated.

If the first three batches which were handled in the small machine are ignored, the period of treatment extended from July 19 to 27. During this 8-day period about 8 tons of bulbs were given the hot-water treatment. Batches 4 to 14, inclusive, were treated for about three hours. Batches 15 to 19, inclusive, all treated in 1926, were given the normal temperatures, but were held in the bath about 90 minutes only. The bulbs handled in these late batches had received a full 3-hour treatment in 1926. The treatment again in 1927 was designed simply to catch any possible reinfestation of the greater bulb fly which might have occurred during the 1927 growing season. This treatment of 1½ hours has proved to be ample to rid stocks of the fly; indeed, no live fly larva has been found after one hour of treatment at 110° F. At the time the hot-water treatment was given the larva was the only stage of the greater bulb fly that was present, and 1½ hours in the hot-water bath was ample for destroying it.

The stocks were treated as they came from the field without being segregated into sizes or worked over. Although treatment after such segregation is preferable, a segregation of these numerous experimental stocks before treatment would necessitate keeping track of and handling an altogether too burdensome number of packages. It was decided, therefore, to obviate this trouble by treating the stocks first and working them over afterwards.

Injury was clearly observable to the bulbs in Great Warley and one lot of King Alfred from the last two batches treated. They were both dried in the more poorly aerated situation in the bulb house and were not subject to inspection and care like the others. Because of the full use of the shelving, they were placed in piles 6 inches high and not examined for over a week after the treatment. Great Warley rotted rather promptly, but King Alfred more slowly. There was a 10 per cent loss in each.

No apparent injury occurred to the bulbs of any other varieties except in cases where there were cuts or bruises. All bulbs thus injured rotted promptly except where the cut surface was thoroughly healed previous to the processing. The treatment seemed simply to hasten decay in these bulbs, for invariably those injured in the digging decayed unless the cut surface was fully exposed to the air. This is the case even in the cool climate of Puget Sound and is much more aggravated in the warmer climate of the Atlantic seaboard.

The field planting began about three days before the end of the treating period and was finished about the middle of August. The stocks were worked over and sized from time to time as required for planting.

While planting started before the treatment ceased, no hot or even wet bulbs were put in the ground. All had cooled and dried before being planted. This is considered preferable even under cool conditions, but still more necessary in hot regions.

The bulbs that went on the forcing benches dried out on the bulb-house shelves from the time of treatment to August 15 or 20 before being packed for shipment to Virginia. Some lots were put in perforated paper bulb sacks and others in ordinary grocer's paper bags and then packed tightly in slatted crates having a capacity of about 8 bushels of loose bulbs. Shipment was by freight with a transit period of a little over three weeks. The carriage was well-nigh perfect.

Five more lots of untreated bulbs were packed loose in identical crates and shipped to Washington, D. C., at the same time, with no losses. Three full crates of treated bulbs of Van Waveren's Giant were shipped to the Coastal Plain Station at Willard, N. C. They arrived a week later and were left in the pack three weeks longer. There was a sprinkling of rotted bulbs when these were unpacked, and the centers of the crates were warm. There was no loss in comparable material of this variety sent to Virginia in a smaller package and unpacked immediately on arrival. Neither was there loss in either treated or untreated bulbs shipped to Washington, D. C., except in one variety, Henry Irving, which had some rot when unpacked and rotted practically completely in the flats.

## CONDITIONS OF FORCING

The handling of these experimental stocks in forcing did not differ from the ordinary commercial procedures. The bulbs were "flatted" or potted in ordinary soil to which a small quantity of bone meal had been added about three months before. The flats and pots were wet down, set away in a frame, and covered with straw. When freezing weather threatened the sash was put on. The middle of December all were placed under cover where no frost would get to them.

In the matter of bringing the flats and pots under and on the benches, the rough commercial practice was also followed. In general, 3 or 4 inches of growth was required before they were put under the benches in a house kept at 45° to 50° F. at night, and buds 1 to 4 inches high were manifest before they were placed on the benches. On the last day of January the heat in the house was advanced 5°, and 10 days later all remaining stocks were put on the benches regardless of their condition.

## BEHAVIOR OF TREATED STOCKS IN FORCING

The hot-water treatment of daffodil bulbs for nematode control is a very simple matter. According to the writer's experience, it consists in holding the stocks in water at about 111° F. for a period of three hours. Any apparatus that maintains this control will suffice. The effect on the stocks, however, is very complicated, for many factors are involved.

The effect on the bulbs and flowers is predicated upon the temperature, duration of the application, condition of the stocks, relation of treating to date of digging, nature of the variety, and possibly other factors unknown at the present time. It may be many years before it is fully appreciated just what the causes of the various phenomena of reaction are. While this is true, there are now sufficient information and experience to warrant treatment with an assurance not only of ridding the daffodil bulb of its more or less serious animal pests but of actually benefiting the general health of the stocks. Whether this general toning up is caused entirely by the elimination of the parasitic organisms, or whether beneficial physiological reactions are brought about, can not now be positively stated, but it can be asserted that the vegetative condition of the Bellingham bulbs has been generally and greatly improved after the hot-water bath has been applied. (Fig. 5.) The writer believes this is entirely due to the elimination of parasites. This condition tallies very closely with observations on commercially treated stocks in both field and greenhouse.

The most obvious visible effect of a severe hot-water bath on the daffodil in these treatments was a dwarfing and malformation of the flowers. (Fig. 6.) This seemed to be affected by both the temperature and the duration of the treatment, modified by the condition of the bulbs and varied with the variety.

So far as it has been possible to determine, as treatments increase in severity the injurious effect on the flowers seems to be progressive. The first reaction seems to be on the petals. It begins in incipient cases in a slight notching about the middle of the perianth segment. This notching may extend to a laceration and soon to a dwarfing of the distal half or even the entire petal. The next part to suffer seems to be the trumpet, which has its flutings modified from a slight slitting to lacerations extending its entire length. Sometimes the frilling is accentuated and in rare instances pleasurably so. In extreme cases the filaments become foliose, giving the impression that the flowers have started to become double.

In general the effect on the entire flower is a dwarfing one, although in the cases of the anthers and filaments there may be an actual enlargement. In but one case, to be discussed presently (p. 26), has there been observed an apparent enlargement of the flower by the hot-water treatment.

In the operations in the season of 1927 two lots were treated the same day they were dug and one lot was treated but four days after digging, which took place as soon as the bulbs were ripe enough to dig. In every case the flowers were modified more than the same stocks treated 15 to 20 days later after the bulbs had dried out on the shelves for that length of time. Very significant is the fact that under the conditions of these treatments out of about 125 varieties and fully 200 lots treated in 1927 only a half dozen, even with but 90 minutes of treatment at full heat, showed no gross blemish in the flowers.

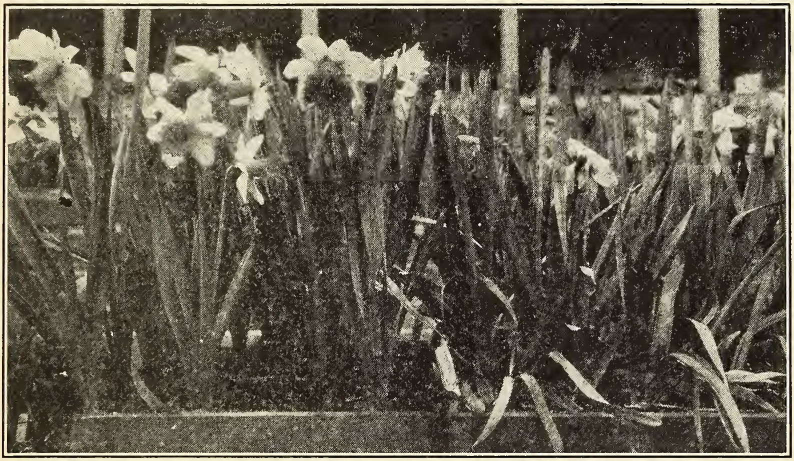

FIGURE 5.—Glory of Noordwijk in early March, 1928. Left, treated in 1926 but not in 1927; right, untreated. The condition of the foliage in the untreated lot is due to Tarsonemus infestation

Whenever there is pronounced modification of the flower form it is often accompanied by a greater or less percentage of blindness (failure to flower). This varies greatly with the variety. The large, robust forms, such as King Alfred, are much slower to express it than such Leedsii varieties as Mrs. Langtry and M. M. de Graaff and such Barrii varieties as Early Surprise.

There does not, however, appear to be any great regularity in the occurrence of this or other phenomena of modification. It may occur pronouncedly even in King Alfred when treated late, as was the condition in one batch given the treatment in early December even when the stocks seemed perfectly dormant. In the flat of this batch, which was forced, there occurred two or three flowers that would be considered slightly modified to the extent of a slight notching of the perianth segments. Two or three were decidedly deformed, but the remainder of the bulbs produced no flowers at all.

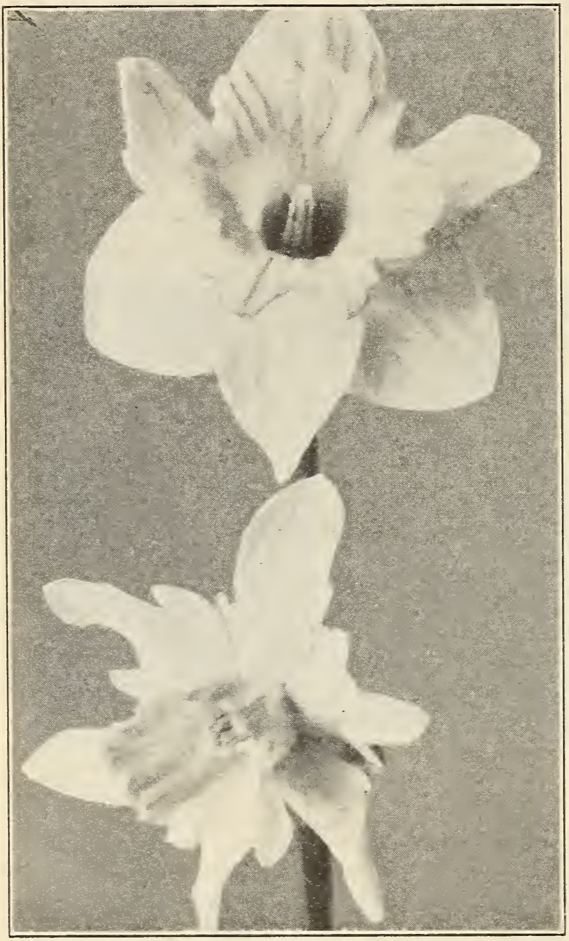

FIGURE 6.—Van Waveren's Giant, forced. Above, untreated; below, treated in batch 13 at 113.4° to 112.4° F. for three hours. Even with this floral injury the vegetative growth was decidedly benefited

The phenomenon of blindness has proved very variable in the treatments employed. It may be manifested by a normal or nearly normal stem with a blasted flower, or the scape may fail to emerge from the bulb, or again there may be any degree of scape development between these two extremes in the same batch treated or even in a single flat forced from the same. When the flower scape fails to emerge, the bulb may be dissected and the dead flower may easily be found in its center. In the 1926 operations, blindness was more prevalent than in 1927. The Leedsii varieties, also Madame Plemp, Weardale Perfection, and others, were especially subject to this form of injury in 1926. While some blindness occurred in 1927 and was most noticeable in these varieties, in no case, even in early treated batches, was it so pronounced as the previous year.

The effect of the different treatments on the leaves is even more interesting than on the flowers. It appears to last only the current season, although there are some inexplicable occurrences which seem to be explained by a hold-over effect of the treatment beyond the first year. The matter requires further investigation.

The bulbs in the 1927 treatments were remarkably free from leaf injuries in comparison with those of 1926. In 1927 there were but few varieties in which there occurred even a slight mottling of the tips of the leaves, with the dots and roughly circular areas in which the chlorophyll was rendered less dense but with no roughening of the surface. The blotched roughening, accompanied by a change in the color of the tissue, took place this year only in the batches treated after the middle of October (pl. 1, A) and one or two lots treated long or hard. Emperor, King Alfred, and Van Waveren's Giant all exhibited this form of injury pronouncedly in late-treated bulbs which produced a good proportion of rather good flowers.

Roughened linear areas along the vascular bundles in the upper part of the leaves occurred in but few varieties. (Pl. 1, F.) It was most noticeable in the flat of Van Waveren's Giant forced from bulbs treated the day they were dug. Even in the few cases where this type of injury occurred, it was insignificant enough to escape attention except under careful scrutiny. It occurred to a slight degree only in Madame Plemp, in which the leaves were somewhat distorted the previous year.

A form of injury which is rather unique was associated with the hot-water treatments in 1927. It was observed in 1926 and the early part of 1927, but was not interpreted until the flats of Great Warley (pl. 1, D) came into blossom late in the season. This form of injury consists of scattered, prominent, oval or elongated, smooth or warty developments commonly on or near the edges of the leaves. The protuberance may be 1 mm. or more in height. When fully developed the growth commonly curls over, presenting a smooth, glossy, ivorylike convex surface, with the distal end somewhat roughened. It has been observed a number of times in the past two years, but its cause was not definitely determined before. It is most likely to occur in scattered lesions, but has been observed in a few leaves to be aggregated when distortion of the blade results. Sometimes the lesion is long, often measuring half an inch, with only a small portion proliferated into the elevated structure, but all lesions present the same appearance.

It is obviously necessary to exclude Weardale Perfection from entry into any of these calculations except as to the effect on the flower, because the Bellingham stock of this variety seems to be rather permanently affected with a roughening of the leaves accompanied by a slight discoloration which simulates the roughening caused by the hot-water treatment. It may be asserted with confidence, however, that constant familiarity with this stock for the past 10 years indicates that it is slowly improving in quality and that this leaf imperfection is gradually disappearing. This imperfection, similar to the result of excessive hot-water treatment, seems to be permanent in this and some other varieties, noticeably some stocks of Crystal Queen. It is referred to by some as a mosaic, concerning which much is yet to be demonstrated.

It may be accepted as generally true that these modifications brought about by treatments are transitory, lasting for the season only. This conclusion is justified by the behavior of the stocks treated in 1926. Of course there may be some hold-over effects, but up to this time none have been definitely proved.

In the treatments made in 1926, Madame Plemp suffered both leaf and flower injury about as badly as any variety treated. A flat of this stock, forced without treatment in 1927, was not only superior in vegetative character to that never treated, but was apparently without trace of treating injury observable up to very early blossoming, when observations ceased owing to the writer's enforced departure for observations in the field. The pronounced leaf injury of 1926 had all disappeared in 1927, and slighter injuries of the same nature in other stocks had entirely disappeared. In no case has the flower modification been thought to persist beyond the first season.

The most impressive phenomenon in connection with the forcing of these treated and untreated bulbs has been the general improvement with reference to the vegetative aspect on the forcing benches. (Fig. 7.) This improvement is far more pronounced in some varieties than others. It has been less pronounced in what has been considered the best doers and most noticeable in the weak varieties or weak stocks of normally good varieties. The vegetative vigor of King Alfred and Van Waveren's Giant has always been good, but the improvement in these was not so noticeable as in Ard Righ, Obvallaris, M. J. Berkeley, and Gloria Mundi, which have always done poorly in previous years. However, there has been improvement in general, and in no case is it thought that there has been a reduction of vegetative vigor even when the blemishes previously detailed have prevailed.

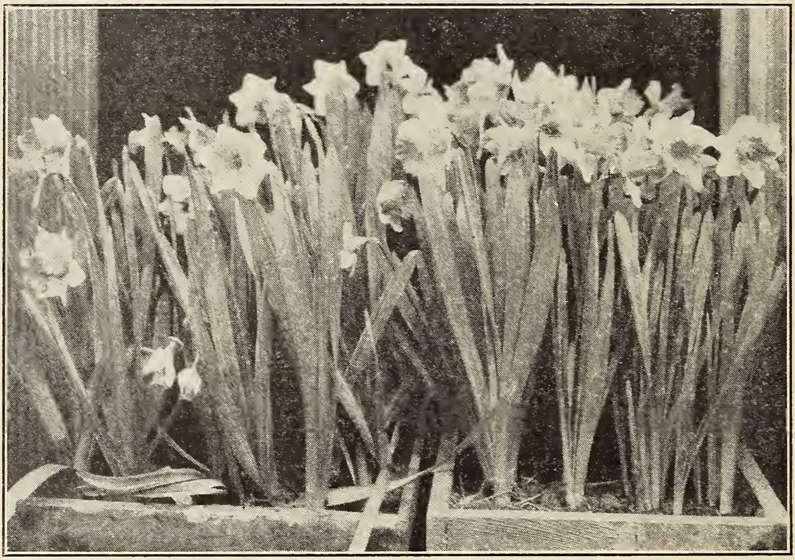

FIGURE 7.—Victoria. Left, untreated; right, treated two years in succession. Note more uniform growth in the treated flat, due to elimination of the Tarsonemus mite

EFFECT OF TREATMENTS ON FORCED BULBS

In the following discussion the varieties are listed under the number of the batch in which they were treated. Following the variety name is recorded the number of bulbs forced (usually one flat), the number of flowers produced, the date flowering began, and a short characterization of the effect on the flowers. The effect on the leaves was so insignificant and slight that it has been disregarded. Other data relative to the experiments are given on page 14.

*Batch 1.*—Treated at 112.4° to 110.4° F. for 3 hours.
  Van Waveren's Giant, 33 bulbs gave 33 flowers; flowering began February 23. The worst deformed lot of the variety. (Fig. 8.)
*Batch 2.*—Treated at 112.6° to 110.8° for 3 hours and 25 minutes.
  Golden Spur, 37 bulbs gave 51 flowers; flowering began February 8. Malformation and dwarfing slight.
*Batch 3.*—Treated at 112.4° to 110.2° for 4 hours.
  Sir Watkin, 35 bulbs gave 64 flowers; flowering began February 20. Badly deformed.
*Batch 4.*—Treated at 111.8° to 111° for 3 hours.
  Ornatus, 36 bulbs gave 14 flowers. Badly deformed and blind.
  Victoria,[5] 107 bulbs gave 117 flowers; flowering began February 22. The worst deformed of this variety.

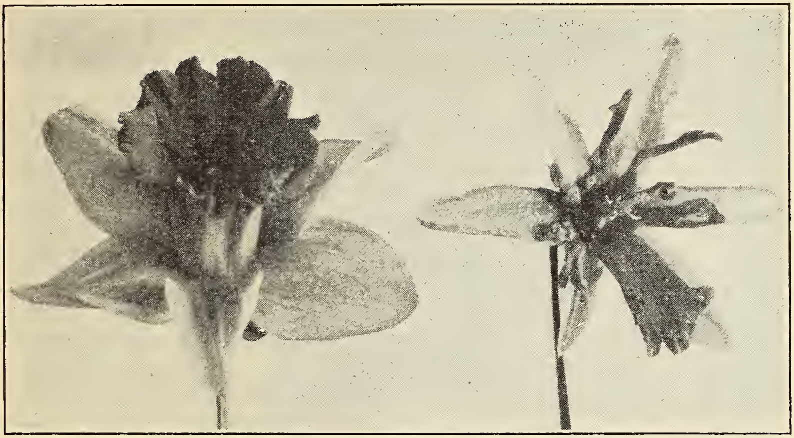

FIGURE 8.—Van Waveren's Giant, field grown. Left, untreated; right, extreme of injury in batch 8 treated at 113.4° to 112.6° F. for three hours. Treatment too severe for forcing, but satisfactory for planting stock from which flowers are not to be cut

*Batch 5.*—Treated at 111.8° to 110.8° for 3 hours.
  Autocrat, 37 bulbs gave 59 flowers; flowering began February 11. Normal without checks.
  Double Van Sion,[6] 39 bulbs gave 38 flowers; flowering began February 8. Pronounced dwarfing of flowers.
  Empress, 39 bulbs gave 43 flowers; flowering began February 23. Badly deformed.
  Golden Spur, 38 bulbs gave 58 flowers; flowering began February 9. Normal without check.
  John Bain, 36 bulbs gave no flowers. Total blindness.
*Batch 6.*—Treated at 111.4° to 110.4° for 3 hours.
  Glory of Leiden,[7] 74 bulbs gave 82 flowers; flowering began February 22. Increased frilling and enlargement.
  Golden Spur, 38 bulbs gave 52 flowers; flowering began February 9. Malformation and dwarfing slight.
  Madame Plemp, 36 bulbs gave 41 flowers. Injury worse than in batch 12.

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[5] Treatment seemed to advance flowering by three or four days.
[6] More green and split trumpets than in the check.
[7] Flowers decidedly modified but to most tastes not injured.

*Batch 7.*—Treated at 111.6° to 110.4° for 3 hours.

Glory of Noordwijk,[8] 40 bulbs gave 41 flowers; flowering began March 5. More deformed than in batch 13.

Great Warley, 19 bulbs gave 24 flowers; flowering began March 16. Badly deformed.

Madame de Graaff, 35 bulbs gave 33 flowers; flowering began February 25. Petals and frill badly lacerated.

Mrs. Langtry, 39 bulbs gave 37 flowers; flowering began March 8. Decidedly modified and much blindness.

*Batch 8.*—Treated at 113.4° to 112.6° for 3 hours.

Van Waveren's Giant,[8] 35 bulbs gave 46 flowers; flowering began February 24. Badly deformed.

*Batch 9.*—Treated at 111° to 109.8° for 3 hours.

Van Waveren's Giant,[8] 75 bulbs gave 121 flowers; flowering began February 23. Petals dwarfed distally.

*Batch 10.*—Treated at 111.4° to 110.6° for 2 hours and 50 minutes.

Minnie Hume, 36 bulbs gave 16 flowers; flowering began February 11. Blindness, dwarfing, and malformation.

Victoria, 35 bulbs gave 30 flowers; flowering began February 23. Badly deformed.

*Batch 11.*—Treated at 111.6° to 110.8° for 4 hours.

Empress, 29 bulbs gave 35 flowers; flowering began March 1. Petals and trumpets badly deformed.

King Alfred, 77 bulbs gave 98 flowers; flowering began February 7 to 10. All flowers injured.

*Batch 12.*—Treated at 111.4° to 110.4° for 3 hours.

Ard Righ, 30 bulbs gave 45 flowers; flowering began January 31. Nearly normal.

C. J. Backhouse, 35 bulbs gave 67 flowers; flowering began February 9. Slight notching of petals.

Emperor, 35 bulbs gave 52 flowers; flowering began February 21. Trumpet fluted and petals dwarfed.

Glory of Leiden,[7] 35 bulbs gave 42 flowers; flowering began February 20. Increased frilling and enlargement.

Golden Spur,[9] 38 bulbs gave 38 flowers; flowering began January 31. Irregular; one-half failed to open.

Madame de Graaff, 35 bulbs gave 32 flowers; flowering began February 25. Petals and frill much lacerated.

Madame Plemp, 35 bulbs gave 40 flowers; flowering began March 12. Dwarfed, blind, and malformed.

Princeps, 35 bulbs gave 41 flowers; flowering began February 17. Slightly modified, but 10 blind.

Victoria, 35 bulbs gave 42 flowers; flowering began February 19. Contraction of petals and trumpet. (Fig. 9.)

*Batch 13.*—Treated at 113.4° to 112.4° for 3 hours.

Elvira, 35 bulbs gave 35 flowers; flowering began February 29. Petals serrated.

Glory of Noordwijk, 35 bulbs gave 34 flowers; flowering began March 5. Petals and trumpet frill affected.

Minnie Hume,[10] 35 bulbs gave 47 flowers; flowering began February 10. Petals notched and contracted.

Van Waveren's Giant, 35 bulbs gave 40 flowers; flowering began February 21. Distal half of petals badly dwarfed.

*Batch 14.*—Treated at 110° to 111° for 2 hours and 50 minutes.

Conspicuus, 35 bulbs gave 54 flowers; flowering began March 5. Slight notching of petals, but nearly normal.

Van Waveren's Giant, 35 bulbs gave 48 flowers; flowering began February 24. Petals dwarfed distally.

*Batch 15.*—Treated at 111° to 110.1° for 1 hour and 35 minutes.

Ariadne, 35 bulbs gave 19 flowers; flowering began February 24. Little notching of petals; much blindness.

Emperor, 35 bulbs gave 48 flowers; flowering began March 1. Nearly normal.

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[7] Flowers decidedly modified but to most tastes not injured.

[8] Leaves slightly roughened at tips.

[9] Dug three weeks early. Two of the bulbs rotted.

[10] Dug three weeks early. Ten flower stems failed to open their flowers.

*Batch 15*—Continued.

King Alfred, 30 bulbs gave 30 flowers; flowering began February 15. Normal.

Sir Watkin, 27 bulbs gave 50 flowers; flowering began February 17. Nearly normal.

*Batch 16*.—Treated at 112.8° to 112° for 1 hour and 25 minutes.

Conspicuus, 35 bulbs gave 69 flowers; flowering began February 20. Injury not noticeable.

Double Van Sion, 39 bulbs gave 60 flowers; flowering began February 16. Apparently normal.

Golden Spur, 37 bulbs gave 44 flowers; flowering began February 1. Normal without checks.

Klondyke 39 bulbs gave 42 flowers; flowering began February 15. Very slight notching of petals.

*Batch 17*.—Treated at 111.2° to 110.6° for 1½ hours.

Glory of Noordwijk, 36 bulbs gave 36 flowers; flowering began March 1. Nearly normal.

Madame Plemp, 35 bulbs gave 41 flowers; flowering began March 8. Petals notched and slightly dwarfed.

Victoria, 40 bulbs gave 49 flowers; flowering began February 29. Slightly smaller than checks.

*Batch 18*.—Treated at 111.4° to 111° for 1½ hours.

Cynosure, 35 bulbs gave 39 flowers. Normal in form, but eight blind.

M. M. de Graaff, 39 bulbs gave 78 flowers; flowering began February 18. No injury apparent.

Mrs. Langtry, 37 bulbs gave 59 flowers; flowering began March 15. Practically normal.

White Queen, 35 bulbs gave 55 flowers; flowering began March 1. Practically normal.

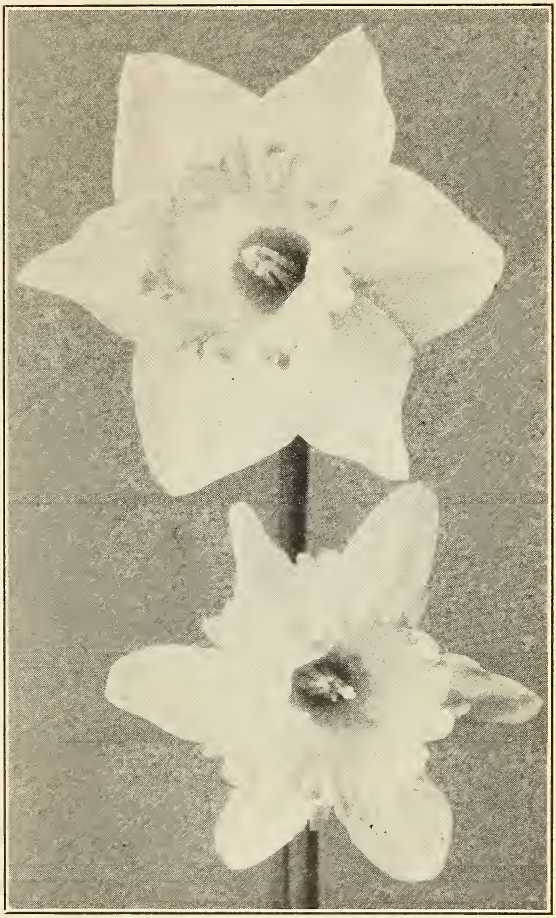

FIGURE 9.—Victoria, forced. Upper, untreated; lower, treated in batch 12 at 111.4° to 110.4° F. for three hours. Injury too pronounced for forcing stock

## THE TREATED STOCKS IN THE FIELD

In a general way the readings on the bulbs in the flats are closely paralleled in the field. In no case do they run contrary, but the field readings dealt with vastly more material and gave an opportunity for a better interpretation of the extremes of modification due to the treatment. Aside from the brief characterizations given under

"Miscellaneous varieties," it seems desirable to comment on certain ones more in detail, either on account of their individual reactions, or their prominence in commerce, or because some lesson is taught from the reactions observed.

## SPECIAL VARIETIES

*Victoria.*—Six lots of Victoria were treated in 1927. Two lots never treated before were handled in batch 4 (111.8° to 111° F. for 3 hours); one lot each, also never treated, in batches 10 (111.4° to 110.6° for 2 hours and 50 minutes) and 12 (111.4° to 110.4° for 3 hours); and one lot each, which had been treated in 1926, in batches 17 (111.2° to 110.6° for 1½ hours) and 19 (111.4° to 110.8° for 1 hour and 40 minutes). These two were consequently given about 1½ hours in the bath.

In no case was there leaf injury, but there was a decided malformation of flowers in all but those treated in batches 17 and 19, where there was only the slightest contraction of the distal portion of the petal.

The very noticeable phenomenon in this set of experiments was the apparent advancement by about two or more days of the date of flowering in the treated stocks.

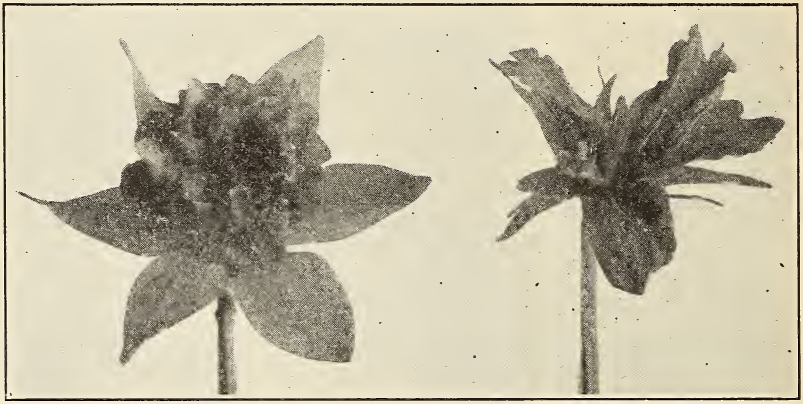

FIGURE 10.—Double Van Sion, field grown. Left, untreated; right, a badly deformed flower from batch 5 treated at 111.8° to 110.8° F. for three hours. The vegetative growth had no blemishes and was much improved

*Double Van Sion.*—The old Lent lily has lost its popularity to a very large extent on account of its habit of turning green and splitting up its flowers into a nonornamental monstrosity. There is abundant evidence that this variety, when properly grown, has a large measure of popularity left and can be produced in the cool Pacific Northwest in quality fully equal to the imported article which is not always perfect. It requires perfect drainage, a cool climate, good fertility, and seems to be benefited by partial shade.

Six lots were treated. It is not at all easy to perceive nor to describe the effect of these treatments on this variety, on account of the peculiar and very diverse nature of the flower.

Two lots were treated in batch 5 (111.8° to 110.8° F. for 3 hours), two in batch 10 (111.4° to 110.6° for 2 hours and 50 minutes), and one each in batches 14 (110° to 111° for 2 hours and 50 minutes) and 16 (112.8° to 112° for 1 hour and 25 minutes). All lots except the last showed a dwarfing of the distal portion of the petals, and usually a laceration of the inner petaloid structures was plainly evident. One lot treated in batch 5 was very noticeable for the large percentage of flowers in which the inner petaloid structures were decidedly reduced and often nearly obliterated, leaving but little semblance of the original flower. (Fig. 10.)

The lot treated in batch 16 was noticeably better than any other. It was more floriferous, the flowers were larger, and the color was not only very much better than the lots treated in batches 5 and 10, but better than the checks which had never been treated.

*Golden Spur.*—Golden Spur, or simply Spur, is a name to conjure with in daffodils. As much of it has been forced as all other Dutch stocks combined, and there is no variety that yet takes its place because it has a good color and is early. It is not an easy variety to grow either in North America or abroad, but with thorough drainage, friable soil, care in handling, and elimination of the organisms that do so much to sap its vitality, by the rather frequent application of the hot-water treatment and the maintenance of proper fertility, as good stocks of it may be grown in the Pacific Northwest as were ever imported. It is more difficult to grow in a warm region, it must be admitted, but not hopeless even there.

There are few varieties of daffodils which vary in character and quality as much as this one. One is smaller flowered and narrow leaved, while another is vastly more robust and larger flowered, having wide and glaucous foliage. The stocks treated contained both of these forms.

Of the field-grown materials six lots were treated, one each in batches 17 (111.2° to 110.6° F. for 1½ hours), 16 (112.8° to 112° for 1 hour and 25 minutes), 14 (110° to 111° for 2 hours and 50 minutes), 2 (112.6° to 110.8° for 3 hours and 25 minutes), and two in batch 5 (111.8° to 110.8° for 3 hours). The greatest modification in the flowers was produced in batch 2 by treatment immediately upon digging; the next was produced in batch 5, which was not particularly different from the one in batch 14. The lots treated in batches 16 and 17 would pass for normal, although even in these there was an occasional notch in the petals which was attributed to the treatment.

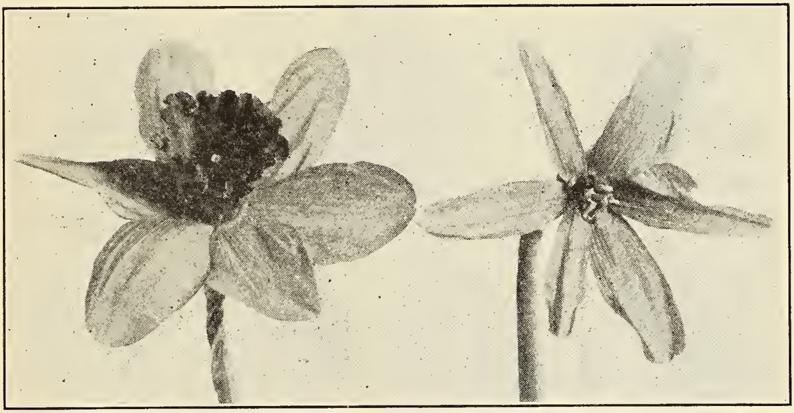

FIGURE 11.—Sir Watkin, field grown. Left, treated in batch 15 at 111° to 110.1° F. for 1 hour and 35 minutes; right, treated in batch 3 at 112.4° to 110.2° for 4 hours the day it was dug. The first shows slight notching and dwarfing but is not seriously injured; the second has no ornamental value but its vegetative growth was improved

The foliage was entirely uninjured in all treatments. The flowering in the treated stock was slightly in advance of the checks.

This set of experiments demonstrates the very high resistance of Golden Spur to injury from hot-water treatment. To the ordinary observer all of these lots would pass for normal and of normal floriferousness, although imperfections could be found in all of them. Even batch 2 needed to be examined carefully to detect the injury, while a casual glance detected the malformations in the other two varieties treated when dug.

*Sir Watkin.*—The giant Welsh daffodil Sir Watkin, in spite of its age, is still a popular variety for forcing. It is of fine form, good color, a reliable forcer, and it has a long, stout stem.

The flowers of the variety were particularly sensitive to hot-water treatments, as was shown in the forcing tests even more clearly, for only two lots, treated in batches 15 (111° to 110.1° F. for 1 hour and 35 minutes) and 3 (112.4° to 110.2° for 4 hours), were field grown. Even the overfull heat for only 1 hour and 30 minutes produced very perceptible notching and a dwarfing of the distal portion of the petal. Figure 11 shows the extreme of the malformations caused by the early treatment in batch 3.

So far as these experiments show, the foliage of this variety is no more subject to injury than that of the others treated, for there was no injury in either batch.

*Van Waveren's Giant.*—This popular and high-priced variety was given a more varied series of treatments than any other. Nine batches were treated between July 7 and November 16. The quantities varied greatly from one-half bushel in the last two lots to a half ton in one of the midseason ones.

The effects of the treatments proved to be as varied as the season, the worst apparent reactions on flowers being obtained in batch 1, treated when dug (112.4° to 110.4° F. for 3 hours), and on the leaves in the two treated at 111° to 110° for 3 hours on October 19 and November 16. The bulbs treated in the last two experiments were held under well-nigh perfect storage conditions in thin layers on shelves in a well-aerated bulb house. Neither the roots nor the tops had any growth in either case, but of course the coats around the basal plate were ruptured and the root tips were pushing but had not broken through. They were in the condition of bulbs held in thin layers in well-aerated, dry situations. Roots do not develop under such conditions in most varieties.

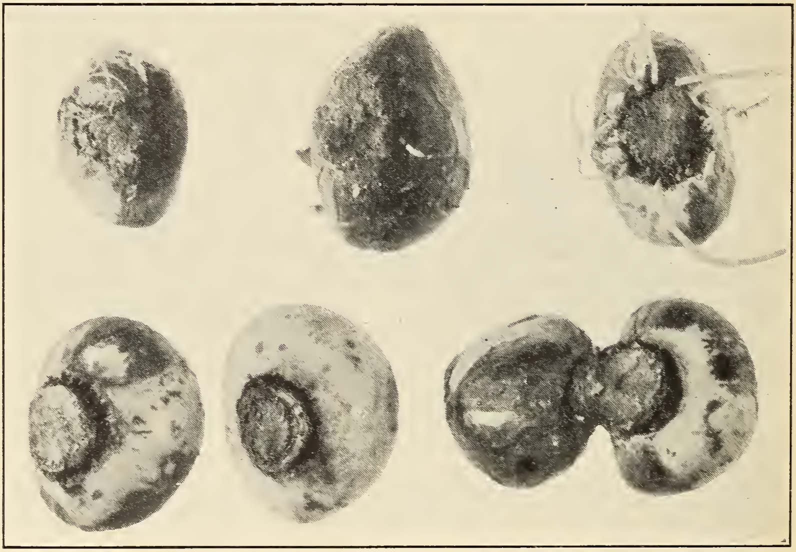

FIGURE 12.—Van Waveren's Giant. Upper row, treated the day they were dug; lower, treated the middle of November. Note difference in the bases. The worst injured in both lots are illustrated

In both the late treatments the leaves of the treated bulbs were of bad color. They spotted and roughened badly, even to distortion and dwarfing, the November batch being decidedly worse affected than the one made a month earlier. But in neither of these late-treated batches were any rotted bulbs found, although 25 per cent or more failed to grow. In all cases the bulbs had made a little top growth, although often not reaching the surface by April 6, the normal time of flowering. Inspections at this time showed that the top growth was in direct proportion to root development, and that the plants which were not appearing aboveground had no roots. It was very evident from an examination of the bulbs that the roots had actually been killed, for there was in all cases a depressed, eroded furrow extending around the basal plate where the roots should be. (Fig. 12.)

In contradistinction to this, the bulbs treated in batch 1 the day they were dug had no leaf spotting or roughening, and most of the plants developed normally. There was some irregularity, however, 5 per cent not appearing aboveground. Inspection of these showed that the bulbs not growing were not only without roots, but they, as well as the few which had diminished tops, were rotted and had the characteristic chocolate purple-brown appearance.

The root ring in the early-treated bulbs presented a very different appearance from the late-treated lot in that the sharply bounded furrow in place of the root circle was absent.

The lack of bulbs failing in the flats from batch 1 may be accounted for by their being hand picked and possibly the best of the stock, but the writer was not conscious of this at the time of selection.

A comparison of the flowers of the earliest and last batches was rather surprising, but not essentially different from other comparable experiences in these experiments. The flowers that opened in these late-treated batches were remarkably normal in their form. There was evident a slight dwarfing; that is, the flowers were smaller than the checks, but the proportions were but little disturbed. On the other hand, batch 1 had its flowers badly deformed, but there was a larger percentage produced by far than in the late batches. The perianth segments were notched, split, and often reduced to a width of one-fourth inch. The trumpets were often so badly split and deformed as not to be recognizable.

A comparison of the flowers of the bulbs treated in batches 8 (113.4° to 112.6° F. for 3 hours) and 9 (111° to 109.8° for 3 hours) is very significant in that it is conditioned upon the one factor of temperature. The perianth segments were much modified in batch 9. They were notched, split, and contracted. These features were very much accentuated in batch 8, and besides the trumpets were lacerated beyond all recognition. The frilling of the trumpet in batch 9 was also modified, but it was simply an accentuation. The modification was in the line of a greater but symmetrical complexity of frilling.

The foliage in batch 8 seemed to be slightly dwarfed in comparison with batch 9. The leaves in batch 9 were perfect in every way, but in batch 8 were slightly roughened at the tips.

Although the temperature employed in batch 8 was comparable with that of batch 13 (113.4° to 112.4° F. for 3 hours), the results on the plants in batch 13 were comparable with those obtained in batch 9 rather than batch 8. There was a difference here in the previous handling of the stocks. Those of batch 13 were dug green the middle of June, three weeks and more earlier than those of batches 8 and 9, the bulbs having been dried in the driest portion of the bulb house during the interim.

A lot treated in batch 17 (111.2° to 110.6° for 1½ hours), full heat and half time, was not seriously modified in gross characters. There was only the slightest notching of the petals.

Two lots treated in batch 14 (110° to 111° for 2 hours and 50 minutes) were not perceptibly different from those of batch 9.

The effect of the treatment on the time of flowering was very slight in all lots except the late October and November batches. The check had the first blossom by a day, which, of course, may or may not be ascribed to the treatment. The October batch opened three or four days later and continued irregularly two weeks after the check. The November batch, while producing one flower only 10 days later than the check, was in general retarded fully two weeks and continued to produce stray flowers until May 1.

There are several lessons which may be drawn from the reactions just described. A difference of 1 degree in temperature makes a vast difference in the reaction on the flowers, but in case of necessity, through nema infestation, the injury in leaf growth and character may be tolerated. The latitude in time of treatment producing negligible injury is considerable, but the middle of October is too late even with the best of storage, and treatment immediately after digging is also severe in the effect on the flowers and causes some injury to the bulbs. There is also furnished a good exhibition of the peculiar effect of treatments on the fluting of the trumpet, which may not be badly injured in appearance to most tastes even when the perianth is ruined.

*King Alfred.*— This variety withstood treatment rather well but was not so resistant to injury as Golden Spur. Three lots were treated, one in batch 15 (111° to 110.1° F. for 1 hour and 35 minutes), which was but slightly if at all impaired in flower quality.

There were two lots treated in batch 11 (111.6° to 110.8° for 4 hours). Both had flowers injured, but one of them, dug June 16 before it matured, was less disfigured than the one lifted three to four weeks later. (Fig. 13.)

*White Queen.*— The two lots of this variety treated in batch 14 (110° to 111° F. for 2 hours and 50 minutes) and 18 (111.4° to 111° for 1½ hours) show more clearly than almost any of the other experiments how unreliable one's estimate may be of the effect of the treatment on the flowers unless checks of untreated flowers are at hand for comparison. The lot treated in batch 14 had a noticeable shallow notching of the petals, but the modification of the form was not pronounced. However, when compared with the check there was a decided and uniform decrease in size extending to all parts of the flower. Even the lot treated in batch 18 had shallowly notched petals rather frequently, but there seemed to be no dwarfing. The check was two days later in flowering.

*Glory of Leiden.*— The peculiarity of the reaction of this variety to the treatment consisted in a general but not entirely uniform, most unusual, and often favorable effect on the appearance of the flower. Two lots of the field-grown stocks were treated in batches 12 (111.4° to 110.4° F. for 3 hours) and 14 (110° to 111° for 2 hours and 50 minutes). The difference between them, as would be expected, was not great; although the notching of the petals, slight in either case, was less in batch 14.

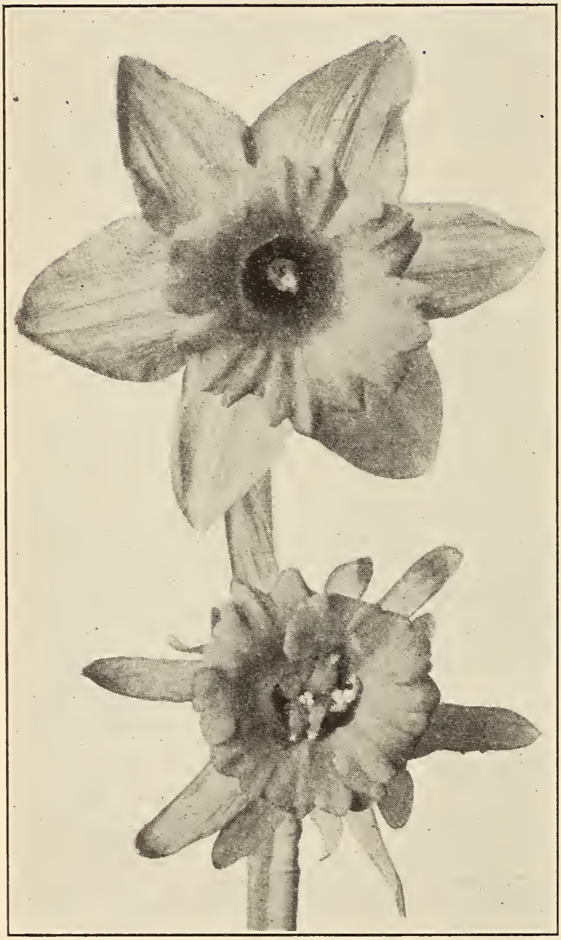

FIGURE 13.—King Alfred, forced. Upper, untreated; lower, treated in batch 11 at 111.6° to 110.8° F. for four hours. This treatment insures an elimination of the nema. The floral injury lasts but one season

Here it was the comparison with the check that was most interesting. No less than seven persons in examining the flowers of this variety pronounced the treated ones superior to the normal. In both of these lots there were about 6,000 flowering bulbs, and there were in all about 3 per cent of malformed flowers with split trumpets. The remainder had actually larger blossoms with but faintly notched petals. (Fig. 14.) The trumpets of the treated lots appeared larger and had both frill and flare accentuated. The mouth of the trumpet in Glory of Leiden was rather simple, but under the influence of the treatment it became complexedly but symmetrically frilled. The diameter of the orifice also increased, so that it became wide open and flaring with an accompanying slight shortening.

This case is interesting from the fact that there was an apparent enlargement of the flower, the only instance in these experiments which could be so construed.

*Conspicuus.*—The two lots of Conspicuus treated in batches 14 (110° to 111° for 2 hours and 50 minutes) and 16 (112.8° to 112° for 1 hour and 25 minutes) will bear careful consideration. The variety withstands the treatment very well, as experience the last two years has shown.

The effects of the two treatments in 1928 were slight and indistinguishable, although one was for about 3 hours and the other for about 1½ hours.

The temperature in the latter, however, was nearly 2° higher than in the former. Both lots would ordinarily pass for normal.

*Double Argent.*—It is often difficult to evaluate the effect of the treatment on the double daffodils. The double Argent variety, however, showed the effect about as plainly as the singles. One lot treated in batch 14 (110° to 111° F. for 2 hours and 50 minutes) reacted very characteristically. The white petaloid structures were contracted, and the yellow inner elements corresponding to the trumpets had the dentation of their edges increased. The injury to the quality of the flower was about equal to that in the single Incomparabilis similarly treated.

*Madame Plemp.*—The experiments with the Madame Plemp variety are of importance mainly on account of the characteristics of the check, which was treated and badly deformed in flower and in leaves in 1926. It has recovered perfectly from both blemishes, the flowers and foliage being normal.

One stock treated in batch 12 (111.4 to 110.4° F. for 3 hours) had flowers badly deformed again in 1928, but there was no injury to the foliage. The modification occurred in the petals and the frilling of the trumpet. The frilling was decidedly more complicated, but it was not enhanced in attractiveness as in Glory of Leiden, and it failed to expand normally.

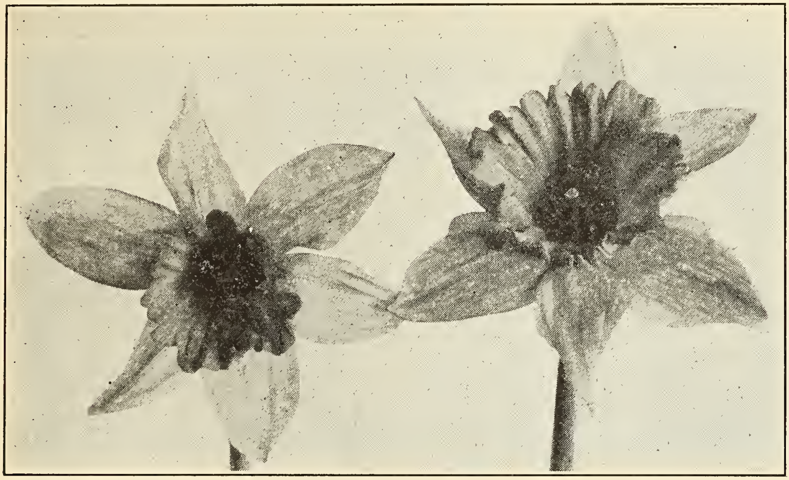

FIGURE 14.—Glory of Leiden, field grown. Left, untreated; right, treated in batch 12 at 111.4° to 110.4° F. for three hours. Note enlargement of the flower and the increase in both frill and flare of the trumpet

Another lot treated in batch 6 (111.4° to 110.4° for 3 hours) had flowers injured much worse, and there was an occasional leaf with roughened lines near the tip. Two elements entered into the comparison of these two reactions. The treatment of batch 12 was three days later than batch 6, but the main significance relates to the fact that the bulbs treated in batch 12 were dug the middle of June, not less than three weeks earlier than those in batch 6.

*Madame de Graaff.*—This variety was conspicuous on account of the apparent forwarding of the blossoming in the treated bulbs. Those in batch 12 (111.4° to 110.4° F. for 3 hours) were less injured than the lot in batch 7 (111.6° to 110.4° for 3 hours). The checks were about four days later in opening than a lot treated in batch 16 (112.8° to 112° for 1 hour and 25 minutes).

The effect on the flower of this variety is conspicuous on account of a pronounced notching, laceration, and narrowing of the distal portion of the petal, and an ugly laceration of the trumpet frill, together with much blindness.

*Great Warley.*—This variety is worthy of special mention on account of the reaction of the foliage to the treatment rather than the behavior of the flower, although that is much injured. Leaf injury consisted of a peculiar, scattered, curved, pimply outgrowth.

The main stock was treated in batch 7 (111.6° to 110.4° F. for 3 hours). About 50 per cent of the plants in the stock bore one to three of these outgrowths on the leaves. Many Great Warley seedlings, given full treatment in 1926 and treated in batch 16 (112.8° to 112° for 1 hour and 25 minutes) in 1927, exhibited the same characteristic in slight degree.

A small lot treated in batch 14 (110° to 111° for 2 hours and 50 minutes) suffered much more leaf injury. Large areas of the leaves were pronouncedly pimply and roughened.

Robert Smith, treated in batch 14 (110° to 111° for 2 hours and 50 minutes), and Kalifornia, treated in batch 10 (111.4° to 110.6° for 2 hours and 50 minutes), were the only varieties that reacted similarly.

The flowers of Great Warley as well as those of many of its seedlings were quite sensitive to the treatments. They became dwarfed, with petals narrowed and incised. The cup had its frill accentuated, its surface more convoluted, shortened, and the flare wonderfully increased by the widening of the orifice. The flowers were less injured in batch 14 (110° to 111° for 2 hours and 50 minutes) than in batch 7 (111.6° to 110.4° for 3 hours), which was a reversal of effect on the leaves. Comparisons with the check showed no dwarfing of growth by the treatment.

*Emperor.*—This well-known old variety was treated in several batches. Two lots were treated in batch 14 (110° to 111° F. for 2 hours and 50 minutes), and one each in batch 12 (111.4° to 110.4° for 3 hours) and batch 15 (111° to 110.1° for 1 hour and 35 minutes). Even the bulbs in batch 15 had flowers decidedly modified, although possibly not commercially injured. There was a slight notching of the petals, and the frill of the trumpets was increased. The two stocks treated in batch 14 had particularly fine foliage, better than any of the others. Unfortunately, each lot of Emperor treated was different; that is, had a different origin. Consequently, the matter of vigor may not be due to the treatment, for, as is well known, there is a marked difference in the natural vigor of different stocks.

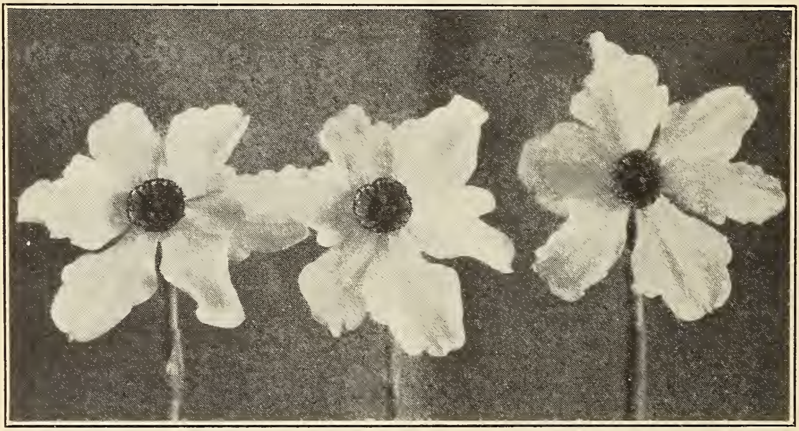

FIGURE 15.—Ornatus, field grown. Serration and ruffling from treatment at 111.8° to 111° F. for three hours

The flowers from batches 12 and 14 were very similar and, while decidedly modified, were not conspicuously malformed, like Victoria, for instance, and there were no lacerated and split trumpets.

One lot of bulbs grown in Virginia and treated in Washington, D. C., November 12, was forwarded to Bellingham, Wash., and planted 10 days later. The plants seemed slightly dwarfed and the foliage mottled and roughened, but the flowers showed slight modification of consequence. There was a slight increase in the frilling of the trumpet, but even this was not conspicuous.

*Ornatus.*—This popular early Poeticus variety deserves special mention on account of the peculiar serration and slight frilling of the perianth segments. (Fig. 15.) This was accompanied by a slight dwarfing of the entire flower. But two lots of this were treated, and both were in batch 4 (111.8° to 111° F. for 3 hours). There was no appreciable effect on the time of flowering, and vegetative growth was good. It is unfortunate that treatment later in the season was overlooked, for it is claimed that the poets in general should be treated early. There was no blindness. No explanation of the blindness of this variety in the forcing tests will be attempted. It may well be due to the handling in the forcing and not dependent upon the treatment. Blindness in the variety is not unusual when an attempt is made to bring it into flower a little too early.

### MISCELLANEOUS VARIETIES

In the following list the temperature and duration of the treatment in each batch are given. Under the batch is listed the varieties treated in each with a brief characterization of the effect of the treatment on the flowers.

*Batch 4.*—Treated at 111.8° to 111° F. for 3 hours.
  Horsfieldii. Injured beyond recognition.
*Batch 5.*—Treated at 111.8° to 110.8° for 3 hours.
  Autocrat. Injury slight and confined to slight dwarfing and notching of petals.
  Beauty. Similar to Autocrat, but more notching of petals.
  Empress. Flowers not recognizable.
  Ideal (Poeticus). Similar, but much less injured than Ornatus (p. 28).
  John Bain. Conspicuous notching and dwarfing of petals.
  Orphee. Notching of petals slight, but there was a slight general dwarfing.
*Batch 7.*—Treated at 111.6° to 110.4° for 3 hours.
  Dorothy York. Similar to Duchess of Westminster (batch 10), but petals more cut.
  M. J. Berkeley. Slight notching of petals only.
  M. M. de Graaff. Petals decidedly contracted, but notching inconspicuous.
  Mrs. Langtry. Decided notching and much blindness.
  Mrs. Walter T. Ware. Injured similarly to but not so badly as Empress (batches 5 and 11).
  Sulphur Phoenix. Outer petals serrated; flowers slightly to much dwarfed.
  Vanessa. Slight notching of petals only.
*Batch 10.*—Treated at 111.4° to 110.6° for 2 hours and 50 minutes.
  Almira. Affected much like Ornatus (p. 28).
  Artemis. Petals slightly ruffled.
  Cervantes. Nearly free of injury.
  C. J. Backhouse. General slight dwarfing of petals and modification of cup.
  Duchess of Westminster. Conspicuous narrowing of petals.
  Elvira. Injury similar but more pronounced than in Ornatus (p. 28); petals notched, laciniate, and dwarfed.
  Gem. General dwarfing and narrowing of petals; cup contracted.
  Golden Sceptre. Petals notched and contracted distally; trumpet injured; flower dwarfed.
  Grandis. Much blindness. Flowers deformed like Empress (batches 5 and 11).
  Gwyther. Conspicuous narrowing of petals.
  J. B. M. Camm. Flowers not recognizable; 50 per cent blindness.
  Katherine Spurrell. Petals decidedly notched and dwarfed.
  Leander. Perianth and trumpet slightly modified and dwarfed.
  Maximus. Petals slightly and trumpet decidedly injured.
  Minnie Hume. Petals badly notched and contracted; cups with increased frilling.
  Mrs. Backhouse. Seventy-five per cent blind; petals badly narrowed and cut, laciniated.
  Mrs. Camm. Flowers in shreds.
  Mrs. Ernst H. Krelage. Petals uniformly notched and contracted; trumpet often split and always with accentuated frilling.
  Obvallaris. Petals shortened, truncated or retuse, and trumpet slightly injured, a striking and unusual modification. (Fig. 16.)
  Olympia. Flowers more deformed than in batch 14.
  P. R. Barr. Flowers badly deformed in all parts.
  Princess Ida. Petals notched and trumpet slit a little.
  Princess Juliana. Flowers badly deformed.
  Splendens. Petals decidedly narrow and cut, laciniate.
  White Wings. Petals dwarfed, cut, laciniate; 20 per cent blindness

*Batch 11.*—Treated at 111.6° to 110.8° for 4 hours.

Empress. Flowers not recognizable.

*Batch 12.*—Treated at 111.4° to 110.4° for 3 hours.

Glory of Noordwijk. Petals cut and laciniate; frilling modified.

*Batch 13.*—Treated at 113.4° to 112.4° for 3 hours.

Dorothy E. Wemyss. Petals notched but shallowly and entire flower slightly dwarfed.

Elvira. Injury limited to slight serration of petals, similar to but less pronounced than Ornatus (p. 28).

Minnie Hume. Petals badly notched and contracted; cups with increased frilling.

Mrs. Langtry. Petals badly notched, evenly serrated, and dwarfed; cups normal.

*Batch 14.*—Treated at 110° to 111° for 2 hours and 50 minutes.

Alice Knights. Petals slightly contracted and frill of cup increased.

Antigone. Petals pronouncedly serrate, frilled by the treatment.

Artemis. Petals slightly ruffled.

Bernardino. Decided notching and contraction of petals.

Blackwell. Slight notching of petals only.

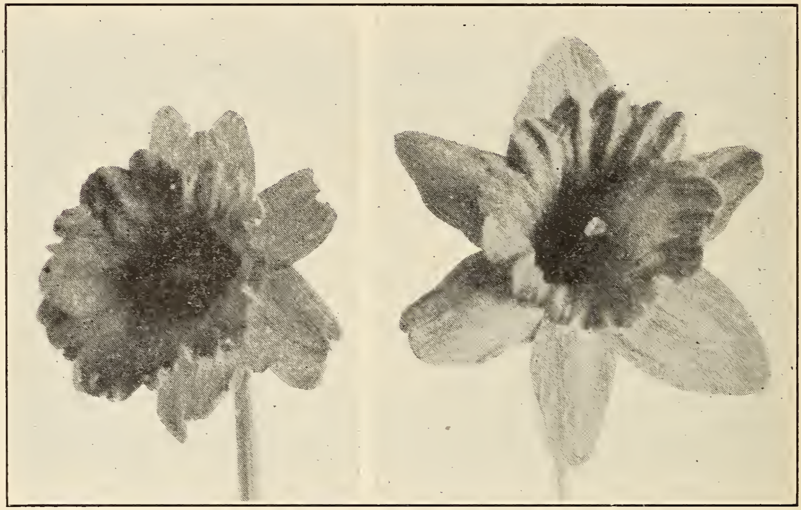

FIGURE 16.—Obvallaris, field grown. Left, petals truncate-retuse from treatment in batch 10 at 111.4° to 110.6° F. for 2 hours and 50 minutes; right, untreated. This is a peculiar modification not noted in any other variety

Bouquet Enorme. Slight notching of petals which is scarcely noticeable.

Buttercup. Injury slight and limited to a little notching of the petals.

Canaliculatus. Injury confined to a very slight notching of the petals.

Cassandra. Injury similar to Ornatus (p. 28) but much less pronounced.

Cossack. Injury slight and consisting of a few dentations on petals.

Eggs and Bacon, Orange Phoenix, and double Golden Rose. Not noticeably affected.

Eurydice. Petals slightly serrate but not injuriously so.

Evangeline. Petals so slightly notched as to pass for normal were it not for slight dwarfing of flower in comparison with check.

Firebrand. General contraction of petals but cups normal.

Haemon. Injury limited to a few dentations on petals.

Hall Caine. Injury very slight; would pass for normal.

Hoboken. Few notches in petals.

Joconde. No injury recognizable without check.

Laurens Koster. Notching of petals shallow; flowers more ruffled.

Lucia. Injury limited to a few dentations on petals.

Lucrèce. Dentation of petals pronounced.

Major. No injury apparent without checks.

*Batch 14*—Continued.

Mermaid. Injury to petals limited to a slight notching.

Mignon. Petals slightly serrated only.

M. M. de Graaff. More injury than in batch 7.

Mrs. G. H. Barr. Entire flower a little dwarfed; petals inconspicuously notched.

Mrs. Harry J. Veitch. Petals slightly notched and contracted but not disfigured; trumpet has increased frill.

Olympia. Flowers scarcely recognizable.

Praecox grandiflora. Petals decidedly notched and contracted.

Princess Louise. Petals slightly notched, rarely cut; cup not changed.

Profusion. Conspicuous notching and contraction of distal portion of petal.

Queen Bess. Petals slightly serrated only.

Queen of the North. Flowers quite serviceable, although shallow notching is prevalent.

Red Star. Decided notching and narrowing of petals.

Robert Smith. Injury to petals apparently slight.

Robert Sydenham. Petals cut, lacerated and lobed, with the frill much complicated.

Seagull. Petals notched, cut, and contracted.

Southern Gem. Slight notching and contraction of petals.

Sovereign. Injury limited to a few dentations on petals.

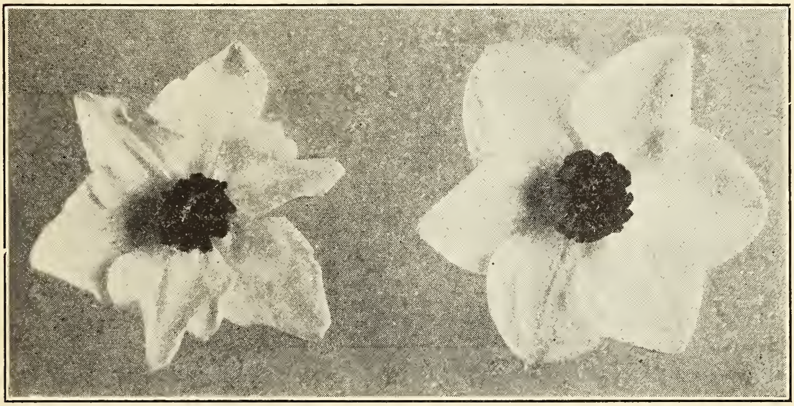

FIGURE 17.—Aspasia, field grown. Serration and ruffling from treatment at 111° to 110.1° F. for 1 hour and 35 minutes

Stella. Petals notched, cut, and contracted; cups not modified.

Torch. Only slight notching or contraction of petals.

Virgil. Considerable shallow notching, but no disfiguring of petals.

Vivid. Petals notched and contracted.

Will Scarlet. Petals badly serrated and cut.

*Batch 15.*—Treated at 111° to 110.1° for 1 hour and 35 minutes.

Ariadne. Notching and contraction of petals evident; no blindness. Compare forced bulbs.

Aspasia. Petals frilled, laciniate; cup contracted. (Fig. 17.)

Dorothy E. Wemyss. Conspicuous notching and laciniation of petals.

*Batch 16.*—Treated at 112.8° to 112° for 1 hour and 25 minutes.

Klondyke. Petals sparsely serrated and sometimes cut.

Madame de Graaff. Notching, laciniation, and contraction of distal portion of petals.

*Batch 17.*—Treated at 111.2° to 110.6° for 1½ hours.

Glory of Noordwijk. Notching of petals inconspicuous and contraction slight.

*Batch 18.*—Treated at 111.4° to 111° for 1½ hours.

Cynosure. Only very slight contraction of distal portion of petals; notching scarcely noticeable.

*Batch 19.*—Treated at 111.4° to 110.8° for 1 hour and 40 minutes.

Glory of Sassenheim. Injury scarcely noticeable.

Sir Francis Drake. Injury scarcely perceptible.

Spring Glory. Injury scarcely perceptible.

*Batch A.*—Imported bulbs treated in Washington, D. C., by the Federal Horticultural Board and shipped to Bellingham, Wash.

Brennin. Slight notching of petals.
Brigadier. No apparent injury.
Early Surprise. Thirty per cent blind; slight serration of petals.
Empire. Occasional slight notching of petals.
Golden Frilled. Occasional slight notching of petals; frill not normal.
Holland's Glory. No evidence of injury.
Ideal (Incomparabilis). Slight notching of petals.
Lady Moore. Slight notching of petals.
Lucinius. Slight notching of petals.
Plato. Slight notching and contraction of distal portion of petals.
Sulphur Beauty. Slight notching and contraction of distal portion of petals.
Sunrise. No injury observable.
Thalia. Injury by notching of petals very slight.
Yellow Prince. Fifteen per cent blindness.

## BEHAVIOR OF UNTREATED CHECKS IN FIELD AND GREENHOUSE

The untreated bulbs planted for field comparisons in 1927 were hand picked out of the entire stocks just before treatments began. Special care was exercised to get typical round bulbs free from fly infestation and other imperfections. They were divested of old coats and roots, and the bases were cleaned.

The performance of these selections in the field in 1928 when compared with their behavior the following winter on the forcing benches was rather remarkable. It was not noticed that there was anything seriously abnormal about them during the growing season of 1928 except that the color of the foliage was often a more glossy green toward the base of the plants, and an occasional leaf in some of the varieties was bent over. This, of course, indicated the presence of the mite *Tarsonemus approximatus* Banks, but the infestation did not appear at all serious. The plants were quite normal in stature, and the inflorescence was all that was to be expected.

These checks were dug in the summer of 1928, dried in the usual way like the other stocks, and forced the following winter. They were, of course, now mostly double-nosed. The bulbs appeared normal except that they might have been considered slightly undersized. They were examined carefully again, as they were the previous year.

Thirty-seven lots of these varieties were planted in 8-inch pots for forcing and handled in the usual way except that they were benched a week or more earlier than usual. After they went on the benches about the first of January, the temperature was put up to 50° to 55° F. at night and held there the remainder of the forcing period. The stocks in general behaved quite badly. Every lot was abundantly infested by the Tarsonemus mite, many to such an extent that the leaves were malformed, curved, twisted, and the flower spikes often dwarfed. There were rust-colored streaks and blotches on leaves and stems. King Alfred, C. J. Backhouse, Autocrat, Princeps, and a few others blossomed quite normally, but all were heavily infested.

The difference in the appearance of these pots and of the flats from the treated portions of the same stocks was very striking. The foliage of the latter was of the characteristic glaucous aspect.

There was also a good opportunity in the greenhouse in 1928–29 to compare the conditions of the stocks from the Bellingham Bulb Station with those of the Arlington Experiment Farm and the Coastal Plain Station, which were untreated. In no case out of more than 50 lots from these two locations was Tarsonemus infestation prominent, and in only a few cases was it detectable. A few specific comparisons on this point are worthy of note.

Sir Francis Drake was imported in 1926, some of the stock being sent to Bellingham, Wash., and some to Willard, N. C. Untreated materials from both locations were forced in 1928–29. That from Bellingham showed slight infestation; that from Willard none. Bulbs of this stock from Willard forced in 1927–28 were suspected of being infested when examined in the dry state in autumn, 1928. A pot of these forced in 1928–29 showed slight infestation, supposed to have been obtained on the forcing benches in the 1927–28 forcing season.

Empress, untreated, sent from Bellingham to Willard in 1925, seemed to be entirely free from Tarsonemus, while untreated bulbs of the same stock from Bellingham were badly infested and the stocks treated in 1927 were free.

Sir Watkin was also sent from Bellingham to Willard and the Arlington farm in 1925, untreated. The untreated bulbs from Bellingham when forced were badly infested. The bulbs grown since 1925 on the Arlington farm were slightly infested, while those from Willard were apparently clean.

Tarsonemus reaction in daffodil stocks has been observed in many widely scattered old plantings in the Pacific Northwest for years without due recognition of its significance. The blemishes have at times been referred to as mosaic maladies. The experiments show that these prevalent blemishes are easily corrected by the hot-water treatment which eliminates the mite. The experiments also seem to indicate that this mite occurs but sparingly at least in regions having warm summers such as Virginia and eastern North Carolina. Indeed, no certain case of infestation from eastern North Carolina has been recognized in any of the materials forced, although untreated bulbs from Bellingham, where the mite is prevalent, have been taken there. Similar conditions prevail in regard to the large bulb fly.

In late July, 1928, two batches of daffodils were treated at Bellingham at 106° to 108° F. for two hours. One flat of 35 bulbs from each of four of the varieties thus treated were forced in 1928–29. It is significant that careful examination of these failed to detect any Tarsonemus blemishes. On the other hand, 45 similar flats of bulbs treated in 1927 but not in 1928 were forced along with the others. To ordinary observation these would be considered perfect, but careful examination showed that at least six of them bore slight but unmistakable evidence of infestation. These stocks were planted in 1927 on ground that had never grown bulbs of any kind.

The main part of the benefit to the Bellingham daffodil stocks from hot-water treatment has evidently resulted from the elimination of the depressing effect of this mite. In the early treatments in Europe the " exhilarating " influence of the treatment was often mentioned, but is not so much discussed now since treating is general. The writer believes that the nonappearance of the effect of the mite in recently imported stock is due to its elimination by hot-water treatments both in Europe and on arrival in this country.

One of the small check lots of Van Waveren's Giant treated at 106° to 108° F. for two hours in late July, 1928, had clean, erect, and glaucous foliage, with no infestation and no floral injury, while another untreated lot was abundantly infested.

The experiments seem to verify the contention of foreign growers that planting stocks of daffodils should receive a "cultural hot-water treatment" at 105° to 108° F. for one and one-half to two hours periodically. The experiments point out at least what seems to be the cause of this necessity so far as the Pacific Northwest is concerned. The evidence presented is not so clear for this requirement in warm regions.

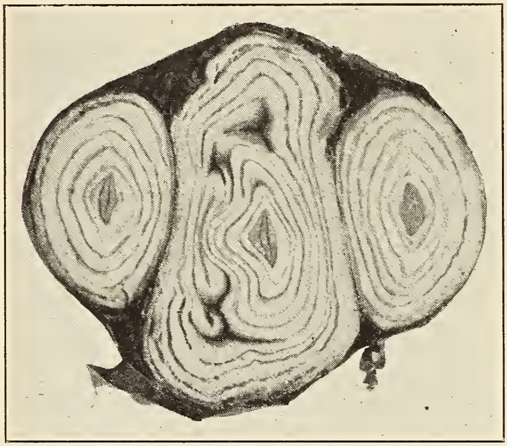

FIGURE 18.—Cross section of a Tarsonemus-infested bulb. The three discolored areas in the looser portion of the center section are an unmistakable evidence of the work of this mite

## REACTION OF BULB TISSUES TO MITE (TARSONEMUS) INFESTATION

The gross blemishes produced on the growing plants by this organism have been considered in another place. A slight or even quite abundant infestation may not be apparent from an ordinary examination of the dry bulbs. Indeed, no criterion has yet been found for recognizing the presence of the mites from external appearances, but any appreciable infestation may be detected if the bulbs are cut open transversely any time during the storage season. At this and other times two or more minute, rusty-brown spots may be seen in the cut surface, most commonly at the opposite sides of the center in the angles where the scales are loose. (Fig. 18.) If cuts are made vertically through these spots, the rusty area will be seen to extend from the snout of the bulb to its basal plate.

So far as observed, the bulbs do not rot from this infestation. The tissues do not seem to be penetrated, the injury being to the external surfaces, which appear to be scarified and turn to a rusty-brown color. The feeding is on the outside of the scales and on other delicate young tissues within the bulbs.

While no criterion can be pointed out for detecting an infestation without cutting the bulb open, any considerable amount of it is reflected in a general poor quality, but there is no specific characteristic by which it may be diagnosed. The snouts appear to be looser and the bulbs lighter in weight and less firm. These characteristics are general, relative, and difficult to judge. The only infallible test is to cut a few bulbs from a suspected lot. Often the general poor condition of the Tarsonemus-infested bulbs may not be due entirely to this mite.

## EFFECT OF TREATMENTS ON THE BULBS

Four men have been thoroughly familiar with the daffodil stocks at the Bellingham Bulb Station for the last 12 years. The improvement wrought by the treatments in the seasons of 1927 and 1928 has been a marvel to all of them. There was no question that the stocks as dug in the summer of 1928 were superior to any that the station has produced in recent years. The elimination of the mite seems to be in largest measure responsible for this improved quality.

The improvement after the treatments was not confined to isolated varieties but was general. Even such a strong grower as King Alfred, while not advanced in quality in the same proportion as some others, showed decided improvement in size, firmness of bulb, and quality of coatings. It was in such weak (with us) varieties as Ard Righ, Obvallaris, M. J. Berkeley, Gloria Mundi, Golden Spur, and Trumpet Maximus that the results were really spectacular. The writer had about despaired of making any progress with that fine old variety, Gloria Mundi, or those deepest of yellows, Trumpet Maximus and M. J. Berkeley. Little increase in stocks was made with them for years, and the bulbs always lacked firmness, size, general quality, and yield. The bulbs of these varieties are now as good as any, and the increase has been phenomenally advanced in a single year.

The benefit from the application of the hot-water treatment when needed, as in these stocks, is very evident. However, a word of caution lest it be applied too often or when unnecessary may not be out of place, for there is usually some decrease in tonnage of bulbs from its use.

## CONCLUSIONS

Daffodil bulbs are best treated four to five weeks after normal digging. They should be thoroughly aerated in the meantime, but injury to planting stock is negligible when treatment occurs after drying but two weeks.

In cases of known nema infestation, it would be preferable to exceed the time of treatment required by the quarantine by an hour, and in case of planting stocks the temperature may be run up to a degree higher, but it is safer to increase the time than the temperature.

Certain varieties, especially the self-yellow trumpets and some Barriis, prove most resistant to injury from hot-water treatment.

Prompt and thorough cooling, drying in thin layers, and good aeration after treatment are imperative. Greater care is necessary in warm weather.

Bulbs treated late in the fall, although not rooted, commonly have the roots killed. They make little or no root growth, often no top growth, and commonly survive and grow the second year, having lost, however, more than a year's development.

Injury to flowers, and even distortion of leaves, from hot-water treatments, seem not to have persisted the second year.

Different seedlings react differently to hot-water treatment, which fact makes it desirable that detailed studies be made of a large number of representative varieties in different groups.

In general, distortion of the flower is more likely to occur when the treatment is given early, and modification of the leaf tissues and injury to the roots when the treatment is given late in the season.

Bulbs to be shipped after treatment should be thoroughly dried, extra well aerated in the pack, and promptly spread out on arrival at destination.

The reaction of the flower to the treatments in the main was dwarfing. The petals became variously notched, cut, and contracted. The frill of the cup became more complicated. As injury advanced, the cup and petals became lacerated and variously modified, and often the flowers were killed.

The reaction of the treatments on the leaves consists of bleached areas near the tips or roughened longitudinal lines corresponding with the veins. These may become confluent in large areas when distortions occur. A few varieties give rise to large conical pimples, 1 mm. or more high.

The work shows quite clearly that daffodil stocks treated after drying but two weeks with a variation in temperature up to 113° F., or the time of treatment extended to four hours, gave no more serious consequences than a little leaf spotting and malformation of the inflorescence for one year.

The readiness with which bulbs seem to become infested with the mite *Tarsonemus approximatus* indicates that periodical treatment may be necessary. Treatment two or three weeks after digging, at 106° to 108° F. for two hours, has eliminated the mite and all other animal organisms except the nema, without apparent injury to the flowers.

Tarsonemus infestation is shown to be at least much less pronounced in regions having warm summers. The same is true of the large bulb fly.

The greatest benefit to the Bellingham stocks from the hot-water treatments has resulted from the elimination of the Tarsonemus mite.

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